Equal class

Implementation of Remote Laboratories

EQUAL-CLASS Project

Analytical Report

Engineers Qualified in Higher Non-University VET Institutions – Providing Arguments and Evidence for NQF/EQF Classification

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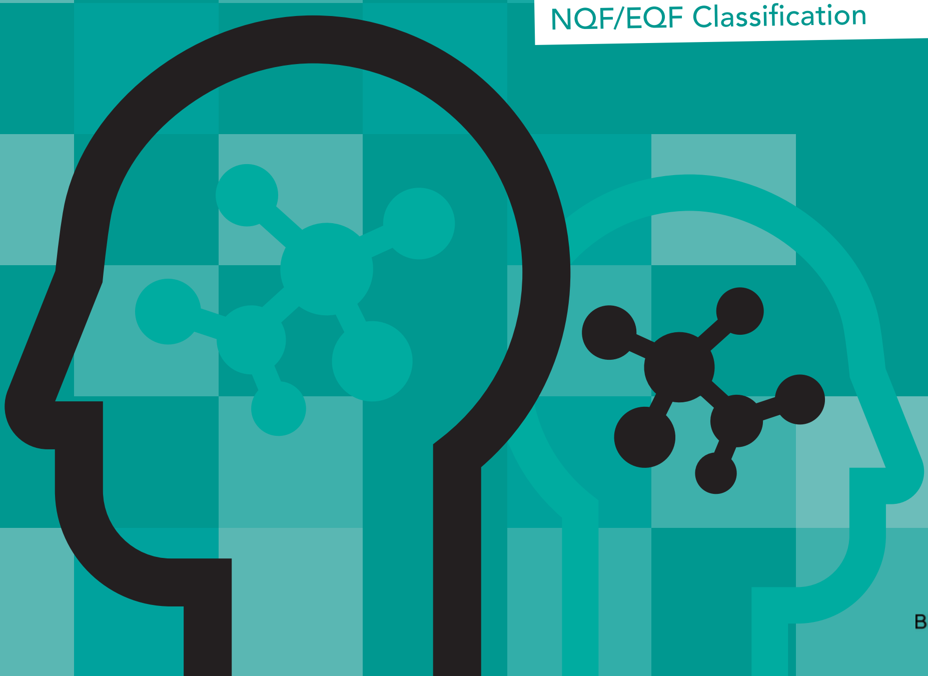

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Written by Urs Keller & Günter Mannsberger

Project Information:

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Project coordinator:	Monika Auzinger, auzinger@3s.co.at 3s Unternehmensberatung GmbH, Vienna, Austria

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Content

Executive Summary

The EQUAL-CLASS project (www.equal-class-eqf.eu) examines qualifications in the field of mechatronics and electrical engineering/electronics that can be obtained in higher non-university VET institutions or comparable institutions in Austria, Germany, Lithuania, Portugal, and Switzerland. The qualifications are assessed from three different perspectives – in relation to learning outcomes, students, and graduates – with particular focus on their NQF/EQF classification.

The EQUAL-CLASS project was funded by the European Commission under the Lifelong Learning Programme (Leonardo da Vinci – Transfer of Innovation). The project ran between October 2012 and September 2014 and was undertaken by a cohort of partners from seven different countries.

This report describes how Programmable Logic Controllers (PLC) installed in so called "Remote Labs" can be accessed remotely through internet technologies, thereby enabling participating VET institutions to support their teaching and learning activities in the occupational fields of mechatronics and electrics/electronics.

This work package aimed to test the applicability of Remote Labs and to bring schools in different European countries together to foster sustainable cooperation in the future development of their laboratories. Another objective was to assess whether comparable information on learning outcomes and additional evidence regarding the classification of comparable qualifications in the field of mechatronics and electrics/electronics could be gained by the use of Remote Labs. It was determined that in order to effectively make such an assessment it would be necessary to a test a group of at least 100 students from different countries.

By March 2014, a total of 164 students from 10 classes in Germany, Austria, Lithuania, and Switzerland had been trained in the use of 30 remote PLC-workstations. Of these students, 150 had logged onto the examination task by the end of May 2014, with 112 passing and 38 failing the examination.

Analysis of the individual examinations and feedback obtained from questionnaires sent to participating teachers and instructors showed that:

- all participating schools fulfilled the minimum requirements and successfully carried out the Work Package 5 reality check
- comparison of qualifications through Remote Labs is limited because the curricula frameworks, subject plans, class schedule, lesson plans and in particular educational objectives, differ between the participating schools.
- Remote Labs support the possibility for students to study in their home location and at their own schedule while maintaining a full-time job, which in turn supports the "lifelong learning concept".

1 Introduction

The term "Remote Labs" refers to „online laboratories used to remotely conduct real experiments". These are scalable (accessible via internet) e-learning instruments especially for use by those studying technical and natural scientific disciplines.

The underlying technology allows for collaboration and (for instance) joint programming in online-laboratories across long distances and national borders. At the same time, tasks can be assigned and undertaken regardless of time and location.

Within the EQUAL-CLASS project all participating students in their respective countries are able to perform programme-related tasks online. The solutions to these assignments can be reviewed online and centrally assessed on a concurrent basis.

The results of the "reality check" undertaken in this work package indicate that participating students with access to Remote Labs studying the occupational fields of mechatronics and electrics/electronics effectively obtained the required knowledge, skills and competences through this instrument.

Work package 5 Reality check 1 – „Remote Labs", which ran from October 2012 to April 2014, was led by ABB Technikerschule Baden. The „Remote Labs" were implemented by the core partners in AT, DE and CH: HTL St. Pölten, ABB Technikerschule Baden, and Grundig Akademie. Moreover, „Remote Labs" were also established at Kaunas College in LT, supported by the Lithuanian core partner Vytautas Mangus University. In all cases, close connections were developed with national schools. Furthermore the implementation of the „Remote Labs" was supported by the associated partner (the enterprises) CEyeClon. In addition, the Siemens Corporation and the Swiss International Teaching Equipment Learning Association (SITELA) supported the implementation and use of the "Remote Labs" on a voluntary basis through the provision of hardware, software, teachware, and know-how.

The original plan was to conduct the "Remote Labs" experiment in five different countries, including Portugal. Unfortunately, however, the Portuguese school which initially collaborated with the project team on the EQUAL CLASS project, and agreed to participate in the Remote Lab initiative, was ultimately unable to take part.

In the initial plan for work package 5 reality check 1 – „Remote Labs"- the intention was to examine at least one class of students in all of the project countries - AT, DE, CH, LT, and PT respectively. Assuming that in European countries, one class typically consists of approximately 20 students, the EQUAL-CLASS project aimed to implement the reality check 1 – „Remote Labs" with approximately 20 students per country, amounting to a total of 100 students.

By March 2014, a total of 164 students had been educated and trained with Remote Labs. Of these students, 150 subsequently participated in the exams.

1.1 Aims of work package Reality Check I: "Remote Labs"

The work package 5 "Reality Check 1: Remote Labs" had the following goals:

- Test the "Remote Labs" among students studying for qualifications in the field of mechatronics.
- Implement „Remote Labs" as a virtual tool that can be used by students in schools in AT, CH, DE, LT, PT.
- Gain additional evidence regarding the classification of comparable qualifications in the field of mechatronics (National Qualifications Framework – European Qualifications Framework).
- Obtain comparable information on the learning outcomes of students/graduates taking qualifications in the field of mechatronics.
- Bring schools in different European countries together to foster sustainable cooperation and secure mutual support in the future development of laboratories.
- Facilitate Europe- wide cooperation between higher (non-university) vocational education and training entities.

1.2 Role of work package Reality Check I: "Remote Labs" within the EQUAL-CLASS project

This work package contributes to the goals of the project insofar as the assessment of the performance of the Remote Labs indicates how students in participating classes in AT, CH, DE, LT, and PT obtain the necessary knowledge, skills, and competences.

Alongside the results obtained from the work packages 4 (comparison from a learning outcomes perspective) and 6 (comparison of graduates' position in the labour market), the results of this work package contribute to the development of a holistic picture of qualifications, teaching content, students, and achieved learning objectives in the selected sectors.
This will contribute additional evidence for the comparison and comparability between European qualifications in the sector of mechatronics and electrics/electronics.

The final report of the work package seeks to address and provide answers to the following questions:

- Are the students in the different vocational schools equally successful in completing their tasks?
- Is the level of difficulty the same across the participating countries?
- Do the students pursue the same or different paths in completing their tasks?
- Can behavioural patterns be identified?
- Can the results be used as additional evidence for the comparability of qualifications and their classification?

1.3 Purpose of this report

This analytical report summarises the work undertaken within WP5 and provides answers to the following questions:

- Are the Remote Labs an effective instrument for competence development in the field of mechatronics and electrics/electronics?
- Are the Remote Labs equally and successfully implementable within the participating organisations?
- Are students from the different VET providers equally successful in completing the tasks?
- Can the results be used as additional evidence in relation the comparability of the classification of qualifications in the field of mechatronics?
- What are the differences and similarities between the results of different countries?

2 Documentation of activities

The implementation of Remote Labs in this work package provided services under the following conditions:

1. Maximum number of workplaces is 30 (for a maximum of 30 students)
2. Maximum number of lessons is 30 (30 hours)
3. Any reservation of Remote Labs for an exercise must be made well in advance at Z&S. (Z&S is the provider of Remote Labs which agreed to support EQUAL-CLASS with know-how and hardware).
4. The S7-1200 control system to operate the system is loaned from Siemens SCE Switzerland and must be returned in two years at the conclusion of the EQUAL CLASS project.

The following institutions participated and contributed to the implementation of the Remote Labs project:

D Grundig Akademie installed 1 Remote Lab in Nürnberg and currently has access to the 30 “Remote Labs” in Biel.

A HTL St. Pölten installed 1 Remote Lab and currently has access to the 30 “Remote Labs” in Biel.

CH ABB Technikerschule installed 2 Remote Labs in Baden and currently has access to the 30 “Remote Labs” in Biel.

CH SITELA, with its three Höhere Fachschulen, installed 30 Remote Labs in Biel alongside with Siemens and Z&S, and coordinated the Remote Labs.

Siemens Schweiz AG significantly assisted the initiative through the provision of with documentation, know-how, and hardware.

Z & S / CEyeClon supported the project through the provision of know-how, an on-site introduction, and hardware.

LT Kaunas College introduced “Remote Labs” and currently also has access to the 30 “Remote Labs” in Biel.

PT Unfortunately, it was not possible to conduct the “Remote Labs” experiment in Portugal.

2.1 Work undertaken in D-A-CH-LT-PT

D

At Grundig Akademie in Nürnberg all teachers were instructed in the use of Remote Labs and lesson preparation was undertaken. Two classes with a total of 37 students participated in the project. The planned examinations for both classes took place in January 2014.

A

At HTL St. Pölten all teachers were instructed in the use of Remote Labs and lesson preparation was undertaken. Four classes with a total of 75 students participated in the project. The students at this institution took the planned examinations at three separate times in 2014: 32 students took the examinations in February; 22 took them in April; and 12 took them in May.

CH

At the ABB Technikerschule in Baden all teachers were instructed in the use of Remote Labs and lesson preparation was undertaken. Three classes with a total of 34 students participated in the project. Examinations for the first class, consisting of 11 students, took place in February 2014, while the examination for the two remaining classes, consisting of a total of 23 students, was planned for August 2014. However, these examinations were performed under different rules to the others because of the strictly defined curriculum and therefore the results were not taken into account for this final report.

LT

At Kaunas College all teachers were instructed in the use of Remote Labs and lesson preparation was undertaken. One class of 18 students participated in the project. The examination of these students took place in January 2014.

PT

Despite considerable effort – made both by the project partnership and the interested school ATEC - it was not possible to conduct the “Remote Labs” experiment in Portugal.

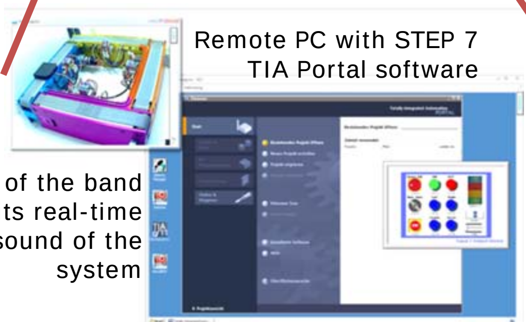
2.2. Teaching Concept with RemoteLabs

This example shows an educational setting with remote workstations on PLC (programmable logic controller) control technology.

Classroom learning:
Learners in control engineering classes enhance their knowledge through operating in a real laboratory environment.

Student PC with free CEyeClon viewer software

Learners work in the classroom:
Learners operate a remote laboratory workstation in real-time using a PC: The student's PC functions as screen and keyboard of the remote PC. A camera image of the remote system is transferred to the screen of the student featuring synchronous sound. This function only requires the free CEyeClon viewer software and any Windows-compatible operating system.



Remote PC with STEP 7 TIA Portal software

Live stream of the band model transmits real-time image and sound of the system

Easy access via Internet:
The viewer software provides access to the workstation and shows it in a media and working window.

Every workstation is physically built up
Remote workstations can be used in real working life. This shows a mechatronic band circulation with a pneumatic transport unit for logistics.

S7 1200 PLC

Network camera

Real conveyor-belt model

Remote workstations in a rack system
Remote workstations can be centrally set up and maintained. Regardless of the actual distance, learners have the opportunity to operate these workstations.

Photo credits: Grundig Akademie, ABB Technikerschule, HFT Mittelland

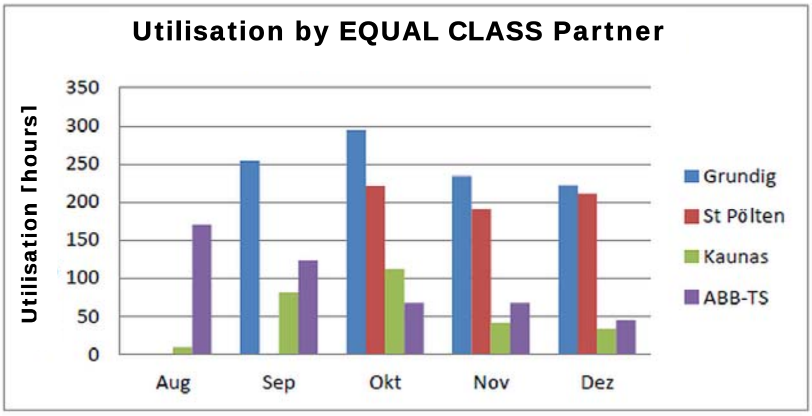
2.3 Timetable

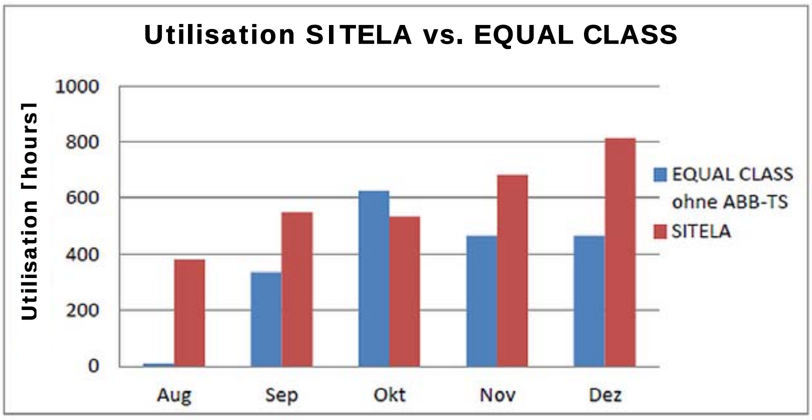
	ABBTS CH	Grundig Akademie DE	HTL St. Pölten AT	Kaunas College LT
• Kick-off implementation Remote Laps	19th Nov. 2012	Nov. 2012	Nov.2012	28th Aug. 2013
• When will the Remote Labs be introduced to all involved teachers?	21st June 2013	11.03.2013	07.03.2013	
• Date of the begin using Remote Labs with the students in the class room	6kt = 2nd April 2013 + 5st = 14th Oct. 2013 + 6kt= 31st March 14	20.09.2013	(at the earliest) 30.09.2013	15 Weeks until 17th December 2013
• When will the test be performed	3 Classes 25. Febr. 2014 Von 15.00- 16.30h 5 st = 17 TN 6 kt 1 in Aug. 14 6 kt 2 in Sept. 14 Reservation ok	Fr. 17. Jan. 2014 2 Classes EDV3b =19 TN von 8:00–10:30h EDV3a =18 TN von 10:30–13:00h Reservation ok	3 classes: 4AHMBA (13.Februar 2014 – 15.10-16.40), ~~4BHMBA (11.Februar 2014 – 15.10-16.40),~~ ~~ev 2 Wochen später~~ 5ABMIA (13.Februar 2014 – 18.40-20.10), 4YHMBA geht sich zeitlich bis Mitte Februar nicht aus. Reservation ok	Tues. 14. Jan. 14 1 Classs= 17Stud. von 10 bis 13h (Litauische Zeit) von 9 bis 12h (Deutsche Zeit) Reservation ok
• When do I get a summary of the results for Reality Check I	5st= latest on the 10th March 2014. 6kt = Aug. 14	latest on the 10th March 2014.	latest on the 10th March 2014.	Feb. 2014

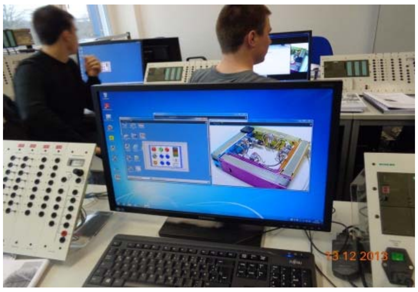
2.4 Analysis of utilisation Aug – Dec 2013

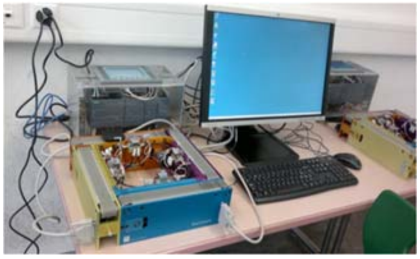
SITELA Smartlogistic S7-1200b

Total utilisation for lectures: 4863 hours
Total utilisation SITELA members: 2959 hours
Total utilisation EQUAL CLASS without ABB-TS1: 1903 hours









1 ABB Technikerschule Baden.

2.5 Exams

The examinations for this project were defined as a series of practical tests based on the experiments/tasks described in chapter “2.3” of the **Reality Check I: „Remote Labs“ design and implementation report.**
These exams were taken by participating students up until the end of April 2014. A statistical summary has been produced for each participating country. For details please refer to chapter “4.1 Description of tasks performed by students during examination”.

All students who successfully passed the examinations (test score better than 50%) were issued a certificate and a certificate supplement, as shown in annex “5.4 Certificate for participating students”.

To ensure smooth implementation of the examinations, an extensive reservation system had to be designed and implemented for the Remote Labs.

2.6 Feedback from teachers and trainers

A questionnaire was designed and distributed to the teachers and/or trainers who worked with the Remote Labs as partners in the EQUAL-CLASS project, in order to learn more about their experience of the experiment.

The aim of this questionnaire was to identify how training with Remote Labs enables the development of skills and competences in the field of mechatronics and electrical engineering/electronics. Analysis of the interviews also assisted in the development of an understanding of the differences of the competence development processes in the different systems of vocational education and training (specifically for the field of mechatronics and engineering). For details on the questionnaire please refer to annex “5.2 Questionnaire sent to teachers and trainers”.

3 Results

3.1 Analysis of students´ results in the partner countries

The following analyses of examinations are based on the results of four participating countries. As outlined above, the Portuguese school that collaborated with us on the EQUAL-CLASS project was unable to participate in the Remote Lab exercise.

A grand total of 164 students distributed among 10 classes in different countries received training through the use of Remote Labs. One of the classes scheduled their tests for a date after the production period for this report and thus the results for this class could not be used. Therefore, this report is based on the results of 150 students.

Number of students educated & trained with Remote Labs	Participants logged on to test		passed		failed	
	Number	%	Number	%	number	%
164	**150**	**91,5**	**112**	**69,4**	**38**	**30,6**

150 students (91.5 %) have logged on and completed the tests through Remote Labs. 69.4% of the 150 candidates passed the exam. For the purpose of this report, the decision was taken not to produce a “ranking” based on the detailed results of the participants, but instead to publish an anonymous summary of classes classified by number:

Class	Participating students per class (%)	Passed (%)	Failed (%)
1	100,0	63,6	36,4
2	75,0	100,0	0,0
3	100,0	83,3	16,7
4	91,7	72,7	27,3
5	100,0	83,3	16,7
6	100,0	38,9	61,1
7	87,0	65,0	35,0
8	150,0	77,8	22,2
9	100,0	94,7	5,3
Average	**91,5**	**69,4**	**30,6**

Observations:

- Class #2 achieved a pass rate of 100%, but only 75% of this class took the examination via Remote Labs.
- The lowest pass rate is 38,9% - this should be investigated further.
- Class #9 achieved a pass rate of nearly 95% with all students taking the exam via Remote Labs.
- One country has both a top scoring class and a low scoring class.
- Results show a Gaussian normal distribution curve.
- Regardless of the average score per country – each country shows top scoring individual student results.
- It can be stated that all participating schools fulfilled the minimum requirements and successfully carried out the WP5 reality check.

Explanations and boundary conditions:
To implement and utilise a tool such as Remote Labs a certain minimum level of qualification is required of both of teachers and students.

The results show that while there are differences between countries in their vocational training systems, motivated teachers and institutions were able to develop the required knowledge and experience in a short time period of time, enabling them to integrate the Remote Labs into their lesson plans and to transmit the knowledge, skills, and competences which allowed their students to successfully pass the examination.

English language proficiency could be a factor in individual results, but this could not be verified in time for this report.

Government regulated lesson plans could not, of course, be altered a great deal in the implementation of this project.

Participating schools had lesson plans with different subject emphasis. For example, some focus more on particular topics than others. Some of the focus areas included physics, electrical engineering, measurement and control systems, digital technology, automation, drive engineering, hydraulics and pneumatics, and the focus of the school influences the background of the students.

Another significant factor is that in some schools PLC-specific lessons are taught in early semesters while other schools leave this teaching until later semesters. Naturally, this may explain some variations in test results.

3.2 Analysis of interview results in the partner countries

A questionnaire (for details refer to Annex 5.2) was used to interview the teachers and instructors in the partner countries to identify how training with Remote Labs contributes to the development of skills and competences in the field of mechatronics and electrical engineering/electronics. Analysis of these interviews also helps to gain an understanding of the differences of the competence development processes between different systems of vocational education and training (specifically in the field of mechatronics and engineering).

The questions referred not only to the results of student examinations (final testing of skills), but also to the overall process of training to work with Remote Labs.

The following areas were targeted and graded by the interviewees:

Overall experience with the Remote Labs

Q2) **How would you rate the effectiveness of Remote Labs as an instrument for competence development in the field of mechatronics/electronics:**

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 2.5

There was not much spread across the countries and therefore Remote Labs can be seen as an effective instrument for competence development in the field of mechatronics/electronics. The teachers and instructors liked working with Remote Labs because it allows for learning without the need for specific time and space requirements. There is room for improvement in relation to tasks and reliability. For direct quotes please refer to Annex 5.3.

Challenges with local implementation and use

Q3) **How challenging was it for your education institution to introduce Remote Labs with its new technology and learning methods?**

(very challenging) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (no challenge at all)

Overall average grade: 2.5

Even though average grade for responses to this question was also 2.5, the individual responses indicate that there was a deal of variability between the partner countries in terms of how challenging they found implementation of Remote Labs, ranging from “very challenging” to “less challenging”.

Q3.1) How difficult was it to successfully apply it in the composite class with many students?

(not difficult at all) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (very difficult)

Overall average grade: 4
The partner countries unanimously considered it "difficult" to apply.

Q4) Did the students have enough prior knowledge, were the students sufficiently qualified for learning PLC with the Remote Labs?

(fully qualified) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (needed much help)

Overall average grade: 4
With one exception, the majority of partner countries found that the students required a great deal of assistance to use Remote Labs.

Q5) Availability of equipment. Were the facilities adequate to the school and does your institution have the adequate equipment?

(fully adequate) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not adequate at all)

Overall average grade: 2.3
The vast majority of the respondents stated that they had "adequate" equipment, with one exception.

Q5.1) How reliable was the internet connection?

(very reliable) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not reliable at all)

Overall average grade: 2.8
Here the picture varies considerably among the respondents, but in summary it can be stated that a little improvement in internet connection may improve experiences with Remote Labs.

Q5.2) Was the internet connection speed and throughput sufficient?

(very fast) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (too slow for work)

Overall average grade: 2.8
The grading in relation to speed demonstrates that respondents had a similar experience in this area to that of the reliability of the connections shown in Q5.1 above. It is safe to say that in order to make use of remote services in education in the future, many institutions will require access to improved internet connections.

EU-wide cooperation among schools

Q6) **How desirable is an international collaboration among schools?**

(very desirable) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not desirable at all)

Overall average grade: 2.5

The individual grades and quotes show that the participating institutions have very different experiences of international collaboration – good, bad and non-existent. It seems that national collaboration is currently more common, and encouraging extensive international collaboration would require the expending of far greater resources to explain the tangible benefits of such cooperation to schools. Otherwise Remote Labs were seen purely as a tool (like many others) that provides advantages in terms of cost- and equipment sharing. For more details and direct quotes please refer to Annex 5.3 “.

How did working with Remote Labs facilitate the development of the following competences?

Q7) **Handling of simple action- and resource oriented projects or exercises and editing them on remote workstations:**

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 1.8

The respondents agreed that working with Remote Labs helped to develop structured programming competences, as is expressed in the direct quotes found in Annex 5.3.

Q8) **Downloading a project in "Operation control and monitoring“, putting this into the PLC and make adjustments:**

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 2.3

The grades and direct quotes indicate that the Remote Labs enabled students to gain competences in loading, modifying, and adapting the programs, but that they had difficulties with error diagnosis. Please refer to Annex 5.3 for details.

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Q9) Deriving the control logic out of a specification sheet:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 2.3

Once again the respondents expressed that students were able to gain basic competences such as reading a specification or structuring a program, but that there is room for improvement in relation to the development of in-depth knowledge in this field, as is expressed in the respondent comments found in Annex 5.3.

Q10) Solving complex automation tasks in defined steps:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 2.3

The average grade does not fully reflect individual experiences here. Similarly to Question 9 students were able to develop basic competences, but within the short time frame of this project they were not able to use and develop complex automation tasks. For details please refer to Annex 5.3.

Q11) Independently derive from possible critical system situations professional solutions and properly integrate their software solutions:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Overall average grade: 2.3

The results for Question 11 reflect those obtained for Question 10 above - the respondent comments, found in Annex 5.3, indicate that there is a great deal of room for improvement.

3.3 Challenges encountered

All participating schools have made significant progress within a short time frame. The PLC Remote Lab is a new technology with new methods and new technical didactics. The introduction of the instrument into whole-class teaching caused uncertainty and an additional workload.

Therefore, all participating teachers and instructors must be commended for their work and for the fact that, for the most part, the challenges have been overcome.

- It must be noted that the questionnaire responses and the analysis of the examination results indicate that the implementation of the PLC was quite difficult for the students, and this is reflected in the fact that the instructors had to provide a lot of support.
- Harmonisation of the basic subjects and the different curricula used at participating schools.
- Teaching of PLC occurs early in some institution's teaching schedules and much later in the teaching schedules of other institutions.
- The participating schools place different emphasis on key objectives during their studies.
- Different institutions use different PLC systems, so effort was required to learn different operating procedures and interfaces.
- Instructors were required to assist some students to overcome their difficulties with the limited human/machine interaction.
- Activities required to utilise Remote Labs, such as establishing a connection, accessing the program, copy, backup, etc., require a certain amount of time thus cutting the amount of learning/working time available – especially if PLC training is allocated a limited number of hours on the teaching schedule.

3.4 Conclusions

The “reality check” performed on the Remote Labs reveals some general observations about the use of the instrument, which are not country dependent but systemic. These should be viewed as recommendations, a foundation on which future work packages of this kind can be based, not only for the EQUAL CLASS project, but also for other pan European education projects.

In participating in the Remote Labs “reality check”:

- All participating students had received a comprehensive basic education in mathematics, physics, electrical and control engineering.
- All participating schools provided a very professional and technical didactical education which accords with actual practice.
- All participating schools employ highly qualified teachers in the area of PLC
- All participating institutions had access to required equipment and applied it successfully
- The PLC infrastructure was the same for all participants and was very professionally maintained and organised

To ensure the results of this “reality check” are comparable, the following underlying conditions were fulfilled:

- The teachers and trainers responsible received the same training, the same teachware and applied the same methods and equipment.
- All students undertook same tasks and exercises.
- All students were require to pass the same predefined examination.

Analysis of examination results shows that differences in the test scores depend less on the student’s skills, and more on the significantly different duration of specific education. Some schools provide only 20 PLC-specific lessons while others provide 140 PLC lessons. Therefore, students bring with them differing levels of PLC-theory and –experience when working with the Remote Labs. The different number of PLC-specific lessons shows in the test scores and also in the amount of support required by the students on “how to use and operate” the systems.

Despite the differing curricula and key objectives of the studies offered by the participating institutions, the following differences and similarities were identified between country results:

- All schools had a certain fraction of “top performers”, i.e. students with a score above 90% of the maximum achievable points. This supports the conclusion that each school offers similar education and enables its students to reach similar qualification levels. It must be noted that only top schools fulfilling the requirements of the work package were selected to participate in the “reality check”.
- Interviews and judgements expressed by participants demonstrate that all students found the final examination to be difficult or challenging and thus the exam appears to have been an appropriate measure for this reality check.

The results only provide limited evidence regarding the comparability of the classification of qualifications in the field of mechatronics, because:

- The curriculum and key areas of education are very different from school to school.
- This special field covers only 2 – 7% of the total learning hours required for the completion of a curriculum of study. Therefore a comparison of the results of PLC-knowledge only is not significantly indicative for the classification of qualifications for this multi-year field of study.

All schools which successfully worked with PLC Remote Labs demonstrated a minimum qualification level equivalent to EQF level 5 (complex self-directed work) in the area of PLC.

Bottom line:
The majority of students passed the examinations even though some had only 20 lessons on the subject of PLC.

However, without adaptation of curricula frameworks, subject plans, class schedules, lesson plans, and in particular educational objectives, the comparison of qualifications by the use of Remote Labs can only ever be limited.

If all institutions utilised the same comparable basic parameters, the qualifications of vocational education in different countries could very well be compared by the use of Remote Labs and the adoption of the corresponding practical methods.

3.5 Recommendations on the use of tools like “Remote Labs” in different schools and countries

The following recommendations can be made based on the experience gained during the Remote Labs “reality check”:

- Expensive equipment - equipment that requires operational expertise and/or significant resources to maintain and organise - can be concentrated in just a few locations but used remotely and shared by organisations in many countries.
- A centralised budget must be available to cover the acquisition and operation of Remote Labs and associated tools.
- Standardised training must be made available to users and provided on-site at participating institutions.
- Participating partners must have a reliable internet connection which enables them to utilise Remote Labs to a suitable level performance.

Using tools such as Remote Labs provides the following advantages and improvements to European VET providers:

- These tools can be used to harmonise education provision in different countries.
- Participating teachers and trainers are motivated to exchange and share experiences and thus improve their courses.
- Remote tools support the possibility for students to study at home and at their own schedule while maintaining a fulltime job, which in turn supports the “lifelong learning” concept.
- Remote tools allow students and instructors to perform both exercises and examinations at any time regardless of their location providing they have access to the internet.
- Teachware can be developed and used on a collaborative and mutual basis, thereby increasing individual teaching efficiency.
- Such tools allow for the exchange of both experiences and best practices among users.

4 Sources

4.1 Description of tasks performed by students during examination

The examination in the field of PLC with Remote Labs is "output-oriented", presenting a typical work situation and requiring students to implement necessary expertise.

Work situation:
The participants were asked to design systems by applying assemblies or components of mechanical engineering, electrical engineering, and computer science and put these systems into operation. The participants were required to configure the system and develop a control program.

Test system to be developed during examination:
Participants were asked to develop a control system for automating a conveyor-belt system – Smart Logistic. For details on the specification refer to chapter "5.1 Specification for PLC project of examination".

Skills tested:
The examination assessed the students' skill levels in the following areas:

- Ability to handle simple projects and exercise (action- and resource-oriented) with the TIA Portal.
- Ability to edit on remote workstations (Remote Labs).
- Capacity to load in an "Operation control and monitoring" project, enter this into the PLC, and make adjustments.
- Develop the control logic from a specification sheet.
- Solve complex automation tasks in defined steps.
- Capacity to independently develop professional solutions to potentially critical system situations and properly integrate software solutions.

Duration:
Time scope of the examination: 90 minutes

Use of documents in the test:
Participants were permitted to use only the following documents during the examination (no self-created or other program listings were admitted)

1. The Template project = Vorlagenprojekt (hardware and I / O list)
2. The Siemens handbooks = Theory = TH
3. Tips and Tricks = FAQ
4. Take-action guides = Handlungsanweisungen = HA

4.2 Assessment and scoring method used for examination

The following PLC evaluation criteria were developed and used by the participating schools to assess the results of their students:

Development: Is there a modular construction of SW (using FC), are "speaking" names used for the variables (e.g .Mx_Automatic)?

Functionality: Results of the task with the different operating modes and the prompts. For example:

- Can be switched between the individual operating modes.
- Can be switched without causing faulty lamp conditions.
- After pressing the stop button, can the flow be continued at the point of interruption?
- Is the timer and counter function implemented in automatic mode regardless of which types of modes are used (CTU, CTD, TON, TOF, TP)?

Maintenance: Can the program be easily extended or upgraded? Did the participant use comments?

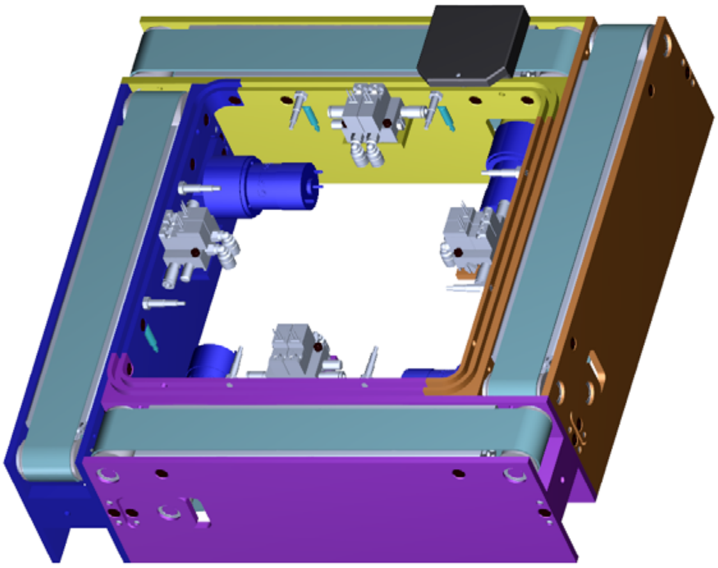
Scoring method: The areas defined above were converted into a scoring table. Participants could achieve a maximum score of 100 with the marks split across several assessment criteria.

Evaluation Criteria	%		%
Development	10	Variable names / symbolism	5
		SW-concept, SW structure	5
Implementation Functionality	70	Mode of operation: manual	10
		Mode of operation: basic position	10
		Mode of operation: automatic	15
		Mode of operation: selective	10
		Sequence repeat	10
		Stop function	5
		Timers	5
		Counters	5
Operation / Maintenance	20	Software testability	5
		Simplicity	5
		Readability	5
		Extensibility	5
Total / Sum	100		100

5 Annexes

5.1 Specification for PLC project of examination

Conveyor-Belt System – Smart Logistic



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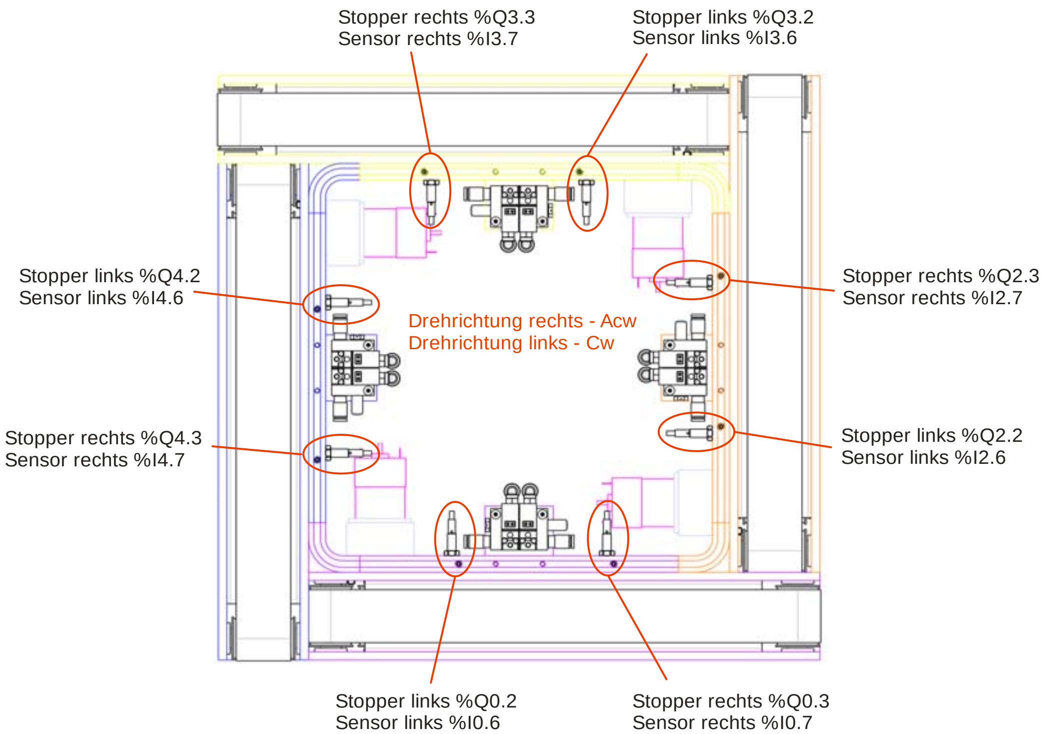


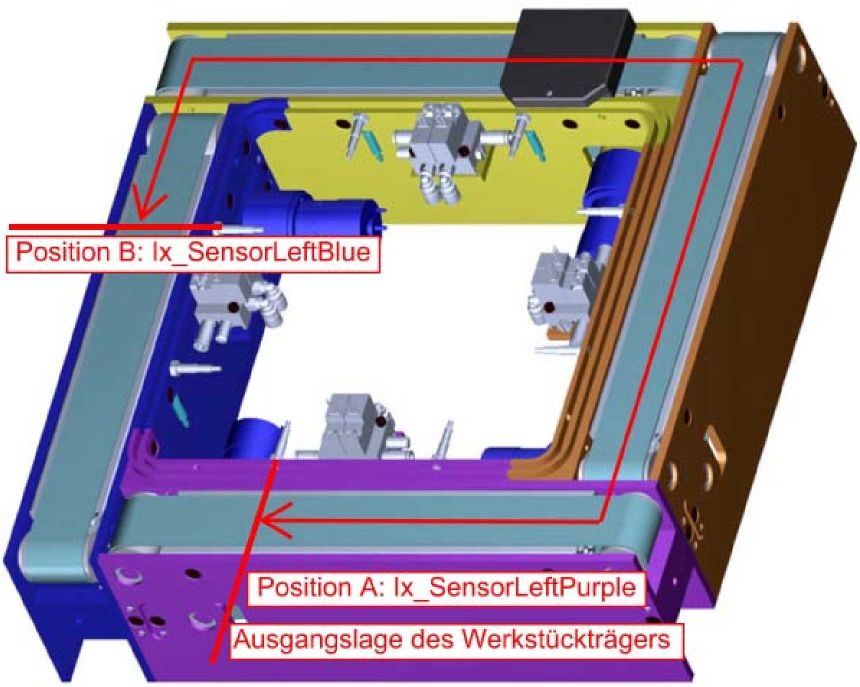
Task Assignment (with timer- and counter functionality, all conveyor-belts with stop function):

General Information:
Think about developing a meaningful structure for your program, and consider readability and future expandability. Correct implementation of both control modes will achieve a score of 70 of 100 potential marks. Program the building blocks, call them via OB1 and assign PLC-operands from the allocation table to the inputs and outputs.

Operating Mode "Manual":

- By pressing the "Left" button, all conveyor-belts can be run so they move left (Cw) at the same time. By pressing "Right" in direction right (Acw) – inching operation
- All pneumatic stoppers shall be inactive (retracted) during this operating mode
- While this operating mode is active, the blue indicator lamp will be lit continuously

Operating Mode "Auto":
The goal of this operating mode is to move the work piece carrier back and forth (Acw and Cw) between the left sensor of the purple belt (position A) and the left sensor of the blue beld (position B). In doing so, all conveyor-belts shall be active. Buttons "Left" and "Right" have no influence on operation during this operating mode.



1. As long as this operating mode is active, a no stop-request exists and the starting position has not yet been reached (see point 2), the yellow indicator lamp shall be lit continuously.
2. By pressing the “On” button, all belts will move in a counter-clockwise direction (Acw) because an undefined position of the work piece carrier exists.
3. If the work piece carrier is detected at the left sensor of the purple belt, all belts must be stopped – starting position “Grundstellung” has been reached. The indicator lamp will change from yellow to green.
4. By pressing the “On” button again, the following sequence will begin:
    - Circuit to the right (Acw)
      Activate all conveyor-belts in a circuit to the right → sensor left blue (position B) → deactivate belts → initiate a waiting period of 2 seconds
    - Circuit to the left (Cw)
      Activate all conveyor-belts in a circuit to the left → sensor left purple (position A) → deactivate belts → initiate a waiting period of 2 seconds
5. Moving back and forth (position A → position B and back to position A) shall be repeated 3 times.
6. Pressing the “Off” button will interrupt this sequence (stopping of all conveyor-belts), the indicator lamp shall change from green to red.
7. After acknowledgement of the stop-function (pressing of the “Reset” button), the sequence shall continue from the position of the interruption. Additionally the indicator lamp will change back from red to green.
8. Resumption of the sequence is possible by “entering at point 4” (starting position has been reached already).
9. After leaving the operating mode “Auto” (transition into the operating mode “Manual”) and re-entering again, a repetition of the starting position is required (entry point 1).

5.2 Questionnaire sent to teachers and trainers

The goal of this questionnaire is to identify how training with Remote Labs contributes to the development of skills and competences in the field of mechatronics and electrical engineering/electronics. Analysis of the interviews may also help to develop an understanding of the differences between the competence development processes in different systems of vocational education and training in the field of mechatronics and electrical engineering/electronics.
In answering these questions please refer not only to the results of student examinations (final testing of skills), but also to the overall process of training to work with Remote Labs (if you have been working with the Remote Labs for a longer period, please also refer to the training you received outside this project).
Thank you for completing this questionnaire. Your responses will be of great value for the work of the EQUAL-CLASS project.

Overall experience with the Remote Labs

Q1) **How would you describe your overall experience in working with the Remote Labs?**

....

Q2) **How would you rate the effectiveness of Remote Labs as an instrument for competence development in the field of mechatronics/electronics:**

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q2.1) Please explain why:

....

Q2.2) Do you have any suggestions for improvements?

....

Challenges with local implementation and use

Q3) **How challenging was it for your education institution to introduce Remote Labs with its new technology and learning methods?**

(very challenging) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (no challenge at all)

Q3.1) How difficult was it to successfully apply it in the composite class with many students?

(not difficult at all) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (very difficult)

Q4) **Did the students have enough prior knowledge, were the students sufficiently qualified for learning PLC with the Remote Labs?**

(fully qualified) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (needed much help)

Q5) **Availability of equipment. Does your institution have the adequate equipment?**

(fully adequate) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not adequate at all)

Q5.1) How reliable was the internet connection?

(very reliable) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not reliable at all)

Q5.2) Was the internet connection speed and throughput sufficient?

(very fast) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (too slow for work)

EU-wide cooperation among schools

Q6) How desirable is an international collaboration among schools?

(very desirable) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not desirable at all)

Q6.1) Please explain why:

....
....
....
....

Q6.2) What are the challenges?

....
....
....
....

Q6.3) What are the opportunities?

....
....
....
....

Q6.4) How can a school participating in a constructive cooperation process - such as that provided by Remote Labs – benefit?

....
....
....
....

Q6.5) Are there any risks?

....
....
....
....

How did working with Remote Labs facilitate the development of the following competences?

Q7) Handling of simple action- and resource oriented projects or exercises and editing them on remote workstations:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q7.1) What kind of knowledge and skills related to this competence did students develop most fully?

....

Q7.2) What knowledge and skills in this field were developed to a lesser extent?

....

Q8) Loading down a project in "Operation control and monitoring“, putting this into the PLC and make adjustments:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q8.1) What kind of knowledge and skills related to this competence did student develop most fully?

....

Q8.2) What knowledge and skills in this field were developed to a lesser extent?

....

Equal class

Q9) Deriving the control logic out of a specification sheet:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q9.1) What kind of knowledge and skills related to this competence did students develop most fully?

....

Q9.2) What knowledge and skills in this field were developed to a lesser extent?

....

Q10) Solving complex automation tasks in defined steps:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q10.1) What kind of knowledge and skills related to this competence did students develop most fully?

....

Q10.2) What knowledge and skills in this field were developed to a lesser extent?

....

Q11) Independently derive from possible critical system situations professional solutions and properly integrate their software solutions:

(very effective) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (not effective at all)

Q11.1) What kind of knowledge and skills related to this competence did students develop most fully?

....
....
....

Q11.2) What knowledge and skills in this field were developed to a lesser extent?

....
....
....

5.3 Quotes from Interviews

The following quotes were been taken from the questionnaire distributed to teachers and instructors involved in the Remote Labs "reality check".

<u>Overall experience with the Remote Labs</u>

Q1) How would you describe your overall experience in working with the Remote Labs?

Work with the Remote Lab has its advantages, because you can access and use it from anywhere. However, due to the given transport system, the application is limited.
We liked working with remote labs. It is a very convenient training and learning instrument, where you can work with real world objects. Another aspect that we liked very much is the provision of the learning and training materials.
Variation in the terms of tasks is very limited.
Reliability of the working stations was not satisfactory.
Students use the possibility to practice outside of the school lessons.

Q2) How would you rate the effectiveness of Remote Labs as an instrument for competence development in the field of mechatronics / electronics?

It is an effective instrument for competence development, because it creates a very realistic, simulated work environment. However, even this kind of work environment cannot compete with the real work environment.
Too many people accessing the system from one class at the same time impairs performance.
The instructions for learning how to program are not detailed enough.
Diversity of the tasks is very limited.
Work methods are effective for basic competences, for complex tasks the work environment is limited.
Remote Labs is good to use for the competence assessment of the PLC programming, as many areas can be covered. However, particular problems can be represented only with great difficulty in simulations, e.g. Inertia of conveyor belts.

Q2.2) Do you have any suggestions for improvements?

Expand the diversity of the tasks.
Portability between different hardware and software support-systems would be desirable (but is this possible?).
It would be interesting to get the analogical visualisation signal of conveyor in order to see the moving parts. Another suggestion is that the work in remote labs is more effective in smaller groups of learners (up to 5).
Training activities should be bottom-up and not just alterations to or completions of existing solutions.

EU-wide cooperation among schools

Q6) How desirable is an international collaboration among schools?

International collaboration in training enables us to demonstrate to students the benchmark of their performance and this motivates students. We have such experience from participation in the international mechatronics competitions.
I can imagine an international cooperation (but our department uses hardware components from another company (Bernecker & Rainer), and thus we have different programming software environment).
Another advantage would support different learning scenarios, communication.
There are obvious direct benefits for the schools.
The main focus is on national collaboration, international collaboration supports the understanding between the foreign colleges of professional education and training.
Because we don't know our collaboration partners, for me the Remote lab is just a tool.

Q6.2) What are the challenges?

There was no collaboration or information exchange between either peer teachers or schools during the trial period. Therefore, collaboration is difficult to imagine. It is not relevant for the final test.
Harmonisation of the basic subjects.
Different educational types; full time, part time.
Different institutions use different PLC systems, to compare them with Remote Lab appears to me to be difficult (learning phase for software operation), and the limited human machine interaction appears to be difficult for some students.

Q6.3) What are the opportunities?

To enrich the competences of students and to increase their employability.
To improve the training processes by accessing different experiences and approaches from the other schools.
To monitor the level of training quality.
"Standardized" comparison of the education of different countries.
Distance education, cost-saving resource sharing.
Enables students to work with devices of the future work environment.
Exchange of students.
Acceptance of educational programme Europe-wide.

Q6.4) How can a school with participating in a constructive cooperation process - such as that provided by Remote Labs – benefit?

Cost savings on hardware, but we have noticed that find it easier to do the tasks when there is a local plant
Remote labs and other similar instruments of constructive cooperation help to increase the training quality and its attractiveness to students, because it deals with concrete practical tasks.
Ability for comparison.
Hardware sharing, the hardware is always up to date.
Fast amortisation of investment.

Q6.5) Are there any risks?

Comparison of schools with different basic subjects.
No free choice on the type of system.
The danger I see is that no longer the plc program development is in the foreground, but the best possible cut at a graduation test – i.e. teaching to the test.
Our schedule provides only a limited time for PLC training, the secondary activities (establishing a connection, accessing the program, copy, backup and so on) require a certain amount of time - the pure working time is thus reduced.
There are no major risks. Sometimes working with remote labs can increase the scepticism and reluctance of students in using this instrument if the quality of internet connection is low or insufficient and there are many disruptions.
It would need adjustments of the curriculum and final tests. Not enough content.

Q7) Handling of simple action- and resource oriented projects or exercises and editing them on remote workstations,

Q7.1) Which skills are developed the most?

Structured program construction.
Skills in working with TEA portal, knowledge and skills in monitoring operations by using TEA portal.
Ability to program simple logical operations.
Ability for abstraction.

Q7.2) Which skills are developed to a lesser extent?

Development of logical thinking.
Maybe the deeper knowledge and skills on how to apply TEA portal in the different simple action and resource oriented projects.
Understanding the programming surface of Siemens.

Q8) Loading down a project in "Operation control and monitoring“, putting this into the PLC and make adjustments,

Q8.1) Which skills are developed the most?

Students always created their own developments of programs - no pre-programs were adapted, troubleshooting and monitoring of the program was difficult for the majority of the students at the beginning – with time and experience, students adapt and perform well.
Skills in programming controllers, TEA portal, basics of monitoring (visualisation).
Can Translate and download programs without difficulty, but error diagnosis is found more challenging.
Can apply test functions

Q8.2) Which skills are developed to a lesser extent?

Configuration of network functions (IP addresses).
Skills for work in the concrete projects of operation control and monitoring - the system is not adapted for the provision of such skills.

Q9) Deriving the control logic out of a specification sheet,

Q9.1) Which skills are developed the most?

Structured programming.
Basic knowledge and skills in deriving the control logic out of specification sheet.
Ability to read and understand data sheet.

Q9.2) Which skills are developed to a lesser extent?

Ability to operate the program.
More in-depth knowledge and skills in this field.

Q10) Solving complex automation tasks in defined steps,

Q10.1) Which skills are developed the most?

With this work environment, complex tasks are not possible.
Applying structured programming.
Very basic knowledge and skills in solving complex automation tasks in defined steps.
In the short time we were able to use Remote Lab no complex tasks were performed, analogue processing, creating own function blocks has not been performed up to this point.

Q10.2) Which skills are developed to a lesser extent?

More in-depth knowledge and skills in this field.
Ability to call modules from OB1

Q11) Independently derive from possible critical system situations professional solutions and properly integrate their software solutions,

Q11.1) Which skills are developed the most?

Can choose correct function element.
Basic knowledge and skills in developing professional solutions to potential critical system situations and properly integrating their software solutions.

Q11.2) Which skills are developed to a lesser extent?

More in-depth knowledge and skills in this field.

5.4 Certificate for participating students

European project for engineers qualified in higher non-university VET institutions – providing arguments and evidence for NQF/EQF classification

European Association of higher educated Professionals
Europäischer Verband für höher qualifizierte Berufe
Association Européenne des Professions Supérieures

European Project EQUAL–CLASS
using PLC (Programmable Logic Control)
and Remote Laboratories

Certificate

We have the honour to inform you that the student

Dominique Muster

Date of birth: 3-Feb-1988

has successfully participated in the PLC (Programmable Logic Control) exercises using the appropriated skills in practical applications with remote laboratories.

The exercises were specified and performed by the European project team EQUAL-CLASS in cooperation with the board of EUROPROF, the institution of the European Association of higher educated professionals.

Wien, March 2014

EQUAL-CLASS Project **EUROPROF**

Lifelong Learning Programme

THIS PROJECT HAS BEEN FUNDED WITH SUPPORT FROM THE EUROPEAN COMMISSION. THIS PUBLICATION REFLECTS THE VIEWS ONLY OF THE AUTHOR, AND THE COMMISSION CANNOT BE HELD RESPONSIBLE FOR ANY USE WHICH MAY BE MADE OF THE INFORMATION CONTAINED THEREIN.

Certificate Supplement

About this certificate:

This certificate, issued in the context of the EQUAL-CLASS project, has been created to reward students for their successful participation in the 'Remote Lab' experiment. It certifies that the learner has successfully completed all assignments to the required standard and has provided sufficient evidence of their PLC (Programmable Logic Control) skills.

About the Remote Laboratory exercises:

Remote Laboratories are online laboratories used to remotely conduct real experiments. The underlying technology allows for collaboration and joint programming in online laboratories across long distances and national borders.

EQUAL-CLASS used these Remote Laboratories to assess students' skills in PLC (Programmable Logic Control) programming. This was carried out within their regular programming classes at school. For this purpose, students in all participating countries were required to undertake the same programming exercises online. The exercises were prepared by the EQUAL-CLASS project team in cooperation with associated partners.

About the EQUAL-CLASS project:

The EQUAL-CLASS project studies qualifications in the field of mechatronics, electrical engineering/electronics that can be obtained in higher non-university VET institutions or comparable institutions in Austria, Switzerland, Germany, Lithuania, and Portugal. These qualifications are examined from three different perspectives: curricula, students and graduates.

EQUAL-CLASS aims to contribute to greater transparency and better comparability of engineering qualifications across Europe. Transparency and comparability of qualifications are important prerequisites for the geographical and labour market mobility of European citizens.

The EQUAL-CLASS project is funded by the European Commission under the Lifelong Learning Programme (Leonardo da Vinci) and runs between 2012 and 2014.

For more information about EQUAL-CLASS, visit our project website:

http://www.equal-class-eqf.eu/

Equal class PROJECT

ENGINEERS QUALIFIED IN HIGHER NON-UNIVERSITY VET INSTITUTIONS – PROVIDING ARGUMENTS AND EVIDENCE FOR NQF/EQF CLASSIFICATION

Comparing qualifications in mechatronics & electrical engineering/electronics

European Qualifications Framework (EQF) levels 5-6
in Austria, Germany, Lithuania, Portugal and Switzerland

3 perspectives

LEARNING OUTCOMES (THEORETICAL – DESCRIPTIVE)

Structured description and comparison of qualifications based on learning outcomes

- Using adapted methodology from the ‚ZOOM' project
- Comparing qualification profiles
- Comparing the assessment of knowledge, skills and competence

LEARNERS (PRACTICAL – PERFORMANCE TESTING)

'Remote Laboratories'

- Online laboratories to remotely conduct real experiments
- Testing learners' PLC* knowledge, skills and competence
- Learners in the participating countries have to solve the same programming exercises online.

* PLC = Programmable Logic Controller

GRADUATES (LABOUR MARKET)

Alumni survey

- Comparing graduates' occupations and positions in the labour market
- Web-based questionnaire in four different languages
  - – Job level and status
  - – Degree of responsibility
  - – Career prospects
  - – Type of tasks executed

+

How can learning outcomes acquired in the workplace be taken into account?

Desk research & interviews

- Validation and recognition of non-formal/informal learning
- Higher NQF/EQF level?

Can the results provide additional evidence for the classification of qualifications in the National/European Qualifications Framework?

Aims: Providing and testing a set of methodological tools

- for transnational comparison
- for the creation of transparency and
- for raising the understanding of a qualification

Further information: www.equal-class-eqf.eu
Duration of the project: 10/2012 – 09/2014
Partners from: Austria, Germany, Lithuania, The Netherlands, Norway, Portugal and Switzerland

Contact:
3s Unternehmensberatung GmbH (project coordinator) www.3s.co.at
Monika Auzinger auzinger@3s.co.at (+43) (1) 585 09 15-12
Viktor Fleischer fleischer@3s.co.at

Lifelong Learning Programme

GRUNDIG AKADEMIE ABB Technikerschule spi HTL ST. PÖLTEN EU pro VET CONSULTUR

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