The 10th International Scientific Conference
eLearning and software for Education
Bucharest, April 24-25, 2014
10.12753/2066-026X-14-195

EFFECTIVE ACADEMIA-INDUSTRY COLLABORATION FOR VIRTUAL INSTRUMENTATION TEACHING AND CERTIFICATION PROGRAM

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***Abstract**: Key point in enabling smooth transition for students from higher education towards the work environment, is represented by a permanent dialogue, exchange of ideas and common projects between the two parties. A positive outcome of such collaborations leads to bridging a gap between academic requirements and applied knowledge using industry standard tools in the workplace. The paper highlights the experiences from the last four years of implementation of the LabVIEW Academy program of the National Instruments company at the Department of Automatic Control and Industrial Informatics, UPB, within the laboratory for Intelligent Measurement Technologies and Transducers (iMTT). The program involves using up-to-date hardware and software for studying and developing complex data acquisition systems and stand-alone virtual instrumentation projects and a commitment to continuous improvement. Industrial software engineering topics are taught and implemented with immediate impact. At a higher level, this focuses on applying modern methods of teaching, evaluation and certification, while making intensive use of eLearning tools. We first describe the program structure, requirements, and benefits along with co-existence with the academic curricula and implementation details. The case study is performed on a relevant sample of more than one thousand students at both the bachelor and master's level and coming from different engineering areas. Student feedback is collected and analysed and means to incorporate this information into subsequent program improvements are discussed. Both quantitative and qualitative evaluation are carried out. We underline the most valuable conclusions towards best practices in actually deploying such programs in specific and general cases for broad applicability across engineering disciplines.*

***Keywords:** industry collaboration; industrial software engineering; virtual instrumentation; engineering education.*

I. INTRODUCTION

Periodic public debates bring in discussion the role of the universities in endowing students with current skills for the requirements of the economic environment. The question is that of a trade-off between theoretical and fundamental knowledge and hands-on experience, acquired during laboratories that keep pace with up-to-date course content and equipment. This comes in the context of broader economic turmoil which has produced extended unemployment across many countries and has especially hurt the younger generation. Solid education and technical skills development for a broad target group has been agreed upon as a valid path to take in order to mitigate these issues at both national and international level. This paper woks upon this context and focuses on medium and large scale structured initiatives offered by large engineering companies in the field of technical education. These can be seen as a bridge between academic achievement and practical skills for new graduates to increase their chances in the initial search for a job in the field in which they have studied. We argue that through permanent dialogue between academia and industry and exchange of ideas, solutions can be identified which are mutually beneficial to the long-term, sometimes divergent, objectives of both sides. Our focus in this scenario regards the implementation in partnership with a large engineering company of program for teaching and certification of graphical system design for virtual instrumentation solutions, addressed to bachelor and master level students of automatic control with focus on measurement, testing and automation technology.

In this context, we first perform a brief survey of related developments in the field. One of the best known and long standing industry initiatives in the field of computer network technology is represented by the CISCO Networking Academy [1]. It aims at blending computer networks academic curricula with company specific solutions practical hands-on training. As for the various forms of implementation, three types stand out: integration into the didactic curriculum, associated to courses of computer networks and systems in computer engineering and industrial informatics, establishing of networking academies in close relationship to the educational institution, which provide optional courses as extra-curricular activities for students or implementation in stand-alone training centres targeting a broader audience including vocational training and adult reconversion. The main value of such programs is given by that of the obtained certification in the market. Another interesting development is represented by the cooperation between EPLAN and the Rheinisch Fachhochschule Koeln [2] for student and specialists training and certification within an academic framework. The main product of the company – EPLAN P8, a solution for computer aided design in electrical engineering, which is a well-known tool across companies working in the field and project management. Here, the main benefits of the stakeholders in this framework are identified. Through such implementation the university stands to benefit from achieving a good reputation, enhance student benefits and free advertisement among technical communities and, if this is further developed it can lead to financial benefits as well. The industrial partner image is improved by collaborating with an academic institution, the path is open for new cooperations and it can profit from the existing skills in the university for curriculum development and validation.

More deeply connected to the focus of this paper, in the field of automatic control and systems engineering, Siemens, a large corporation, operates the "Siemens Automation Cooperates with Education" program [3]. Phoenix Contact, a dynamic competitor, has developed recently the "EduNet International Education Network" which brings together universities from around the world under a common platform. Similarities among such programs include preparation stages to establish such partnerships like instructor training, mostly standardized laboratory hardware and software platforms and courseware and regular updates. We focus on the National Instruments LabVIEW Academy program, which, after careful analysis was found as best suited to the teaching and research interests of the group. To the best of our knowledge, though the program structure and benefits are freely available to the general public, this is the first paper with an in depth view detailing implementation details along with the appropriate evaluation of the program outcome over several years in a technical university environment.

The rest of paper is structured as follows. Section 2 describes the core National Instruments LabVIEW Academy program structure and benefits along with the specific integration concerns of the academic curricula with the virtual instrumentation in depth training content within a series of courses dedicated to measurement and instrumentation in control systems. Section 3 provides a detailed overview, with quantitative and qualitative evaluation of the results achieved by implementing the program between the 2010/2011 and 2013/2014 academic years, including student evaluation of the course and feedback. Section 4 focuses on the optional certification component through which students can become officially certified as virtual instrumentation associate developers, by using modern on-line testing and certification tools. Finally, Section 5 concludes the paper and outlines the main directions for future development and extension.

II. LABVIEW ACADEMY PROGRAM: PURPOSE, STRUCTURE AND OUTCOME

The National Instruments (NI) company is an American multinational organization which first developed the graphical programming language and the virtual instrumentation development environment LabVIEW (**Lab**oratory **V**irtual **I**nstrumentation **E**ngineering **W**orkbench) [5] in the 80s. It was designed as a mean for engineers and scientists to efficiently develop complex systems for PC-based measurement, testing and automatic control, in close integration with suitable data acquisition and control systems hardware. Over the last twenty years, as LabVIEW has turned into a robust platform and achieved large scale usage the industry and thus so has also the relevance to the study of electrical engineering related disciplines. This has lead to steady adoption in academia associated to teaching and research activities in measurement, control and the development of industrial information systems, but also to overarching activities such as online engineering and remote laboratories across a wider domain of disciplines [6]. The main element of LabVIEW is the graphical programming language G which in comparison to conventional text-based programming languages enables intuitive development and quick grasping of essential software development concepts like efficient design patterns and parallelism. As virtual instruments aim to replicate real laboratory and field equipment in a software-intensive environment, having available many functions, extended libraries and graphical user interface elements such as indicators, buttons and graphs, also represents a significant benefit.

The LabVIEW Academy program [7] was initially launched in the United States in 2008 as a way to promote the use of the virtual instrumentation among current students as future specialists in this technology and also to provide a certified consistent set of materials and best practices in teaching LabVIEW and deploying course content. The program currently enrolls over 182 academies in 35 countries, number which stands proof for the interest which this kind of structured industry-academia collaboration framework has provoked among the higher education engineering institutions worldwide. In Romania, along with the implementation at the University "Politehnica" of Bucharest which makes the main subject of this work, subsequent implementations at the University Transylvania of Brasov and the University "Lumina" of Bucharest have been carried out. An online platform for exchange of ideas and support both in relation to the parent company and, more interesting, between participating academies at both student and instructor level, is also provided.

2.1. Program requirements and benefits

The formal requirements of the program will be detailed. First, in order to establish a LabVIEW Academy, the core teaching team has to be made up of CLAD (Certified LabVIEW Associate Developer) certified instructors. This is the first level of achievement in designing graphical systems for measurement and automation, using virtual instrumentation and data acquisition hardware. In the three step, NI certification program this level is followed by the Developer (CLD) and Architect (CLA) certifications. Regarding the course content, there are two options: using official NI provided materials in the form of the LabVIEW Core 1 and Core 2 manual and exercise books along with support content or using own instructional either existing or newly designed for the course. The second options assumes a mutual agreement between the university and the company which has to validate the for a minimum required content. One of the important contributions of this paper is the curricula design particular to our implementation of the program which takes the second option and blends the stringent requirements with a theoretical scientific orientation in the field of measurement systems with elements of technical training and valuable practical knowledge for engineering teaching [8].

Some quantitative requirements include a minimum number of 30 hours per semester of class training along with 20 hours of individual study in the form of homework and 20 hours of LabVIEW-based development projects. The hardware requirements are limited to at least one PC with up-to-date software for every two students in the designated dedicated laboratory and using specific data acquisition hardware. This does not have to be provided by the National Instruments but can be a multifunctional device with analog/digital input/output channels and connectivity via standard interfaces: USB, Ethernet, PCI, PXI, etc. with LabVIEW integration in the form of third party drivers. A support IT infrastructure has to be in place in order to facilitate the download and distribution of learning content to the students and enable their active involvement in the course.

The program benefits address both students at an individual level and the teaching process. Reference course material and software is periodically updated and teaching is performed by certified instructors. Every student that is enrolled in the program receives a free software license for personal use of the current version of the LabVIEW development environment, which does not expire and can be used for other university related projects. They also are encouraged to take on individual study and enroll in a certification exam for the first level of NI LabVIEW certification – CLAD. An examination session has been carried out for the last 4 years in February, the first didactic week of the next semester after the main content related to the LabVIEW Academy has been studied. This is also free for students and they can retake the exam for recertification anytime during their studies.

2.2. An approach to integrate course content with the academic curricula

The academic unit which implemented this program is the Laboratory for Intelligent Measurement Technologies and Transducers (IMTT) at the Faculty of Automatic Control and Computers, UPB. One of the main responsibilities of the group is to offer courses and carry out research activities in the fields of instrumentation and measurements as vital components of automatic control systems. This comes in close relationship with the basic idea underlining virtual instrumentation as an innovative mean to integrate advanced measurements in a complex PC-based development system for testing and automation [9]. Starting with an introductory for 1st year automatic control students covering topics in experimental measurement data processing, "Information Processing" (PI) and going to the core target group represented by 3rd year students of the course "Transducers and Measurement Systems" (TSM). At the master's level, the course "Process Instrumentation in Information Systems" (IPSI) for the direction of Automatic Control and Industrial Informatics in provided. Also a is course offered to 3rd year Mechanical Engineering students, "Sensors and Transducers" (ST), whose students can also benefit from the program.

The main idea behind integrating the provided course content with existing academic curricula towards enhancing student's opportunities for both scientific development and practical training for the workplace is shown in Figure 1. A customized eLearning platform, based on the ubiquitous Moodle solution [10] is used to disseminate all relevant course material, maintaining constant dialogue with students and collecting feedback at the end of the course. Thus, they can receive timely notification regarding the teaching activities, projects and student workshops. As a way to incentivize them for higher involvment a series of quizes along with symbolic e-rewards, like badges, are offered for the most meritous of them. Exploiting the newest features of the open platform is seen as a good way to keep up the pace with modern eLearning and teaching methods.

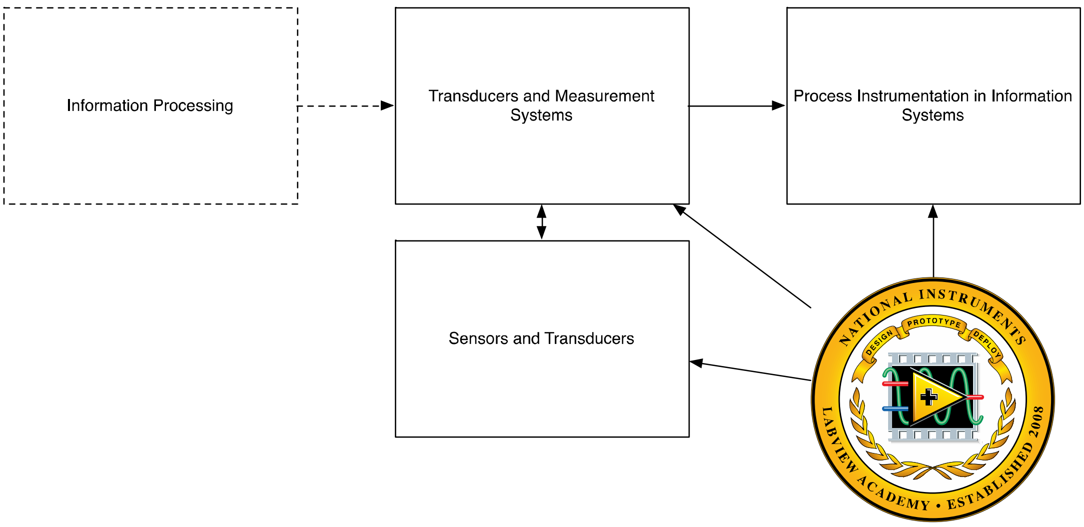

Figure 1. General concept and associated courses

Laboratory structure is organized in three stages. The first one is dedicated to fundamentals of transducers for different measurements. It includes the following subjects:

- Study of temperature transducers;
- Study of pressure transducers with piezoresitive sensitive element;
- Study of analogue-to-digital converters.

Second part is reserved for teaching the basics of the LabVIEW environment and graphical programming. This covers an introduction in LabVIEW, creating virtual instruments and notions and advanced procedures for LabVIEW programming. Also virtual instrumentation for generation and visualization of signals and mathematical function graphics is covered in relationship with previous courses as a mean to apply theoretical knowledge to practical simulation based learning. The third part requires students to integrate data acquisition systems with more advanced virtual instruments in order to acquire, process and generate analogue and digital signals, up to process data acquisition and basic control tasks through multifunctional boards and software development.

Data acquisition hardware which is used starts from basic multifunctional modules with both analogue and digital inputs/outputs and USB connectivity e.g. DataQ DI-158U, NI USB-6008/9. Internal PCI boards for improved measurements: high channel number, increased resolution and sampling rates. The most complex devices used in the framework of the academy include FPGA-enabled real-time input output devices and embedded controllers like the NI RIO 7833R and CompactRIO platform with suitable modules for software defined reconfigurable measurement systems. Modern wireless technologies are covered by working with wireless sensor network based development kits. All the devices mentioned above are integrated directly through the LabVIEW Professional Development System and additional toolkits and modules are provided: Control Design and Simulation, System Identification, Controls and Embedded and Signal Processing and Communication.

III. ANALYSIS OF THE PROGRAM IMPLEMENTATION

During one semester third year students have to go from having basic knowledge of electrical engineering related topics to understanding the basics of process measurements for, the general structure of industrial transducers, and interfacing with dedicated data acquisition systems. Master students go through a more advanced and focused course in the field of process instrumentation and their activity is more project oriented with a significant research component, using provided tools. After the program, both categories should be able to design, implement and validate an industrial measurement and data acquisition system, by means of virtual instrumentation, at different complexity levels. Laboratory activities in relation to the core program implementation cover 2 hours per week during the 14 weeks of the winter semester. Over 80% of the curriculum involves either learning the G programming language or the LabVIEW development system or designing and implementing data acquisition applications with dedicated hardware. Students use as reference a laboratory handbook suited to the specific original content of the academy, and have access to the official NI documentation represented by the Core 1 and Core 2 manuals and exercises as well as online available resources. The program officially debuted in the winter semester of the academic year 2010/2011 with 3rd year and first year master students. Starting from the next academic year, also students from the Mechanical Engineering faculty were involved in the program. As they do not have the same number of application hours, the content is thus adapted and the ones who manifest a special interest have the opportunity to make up for this through individual study and counselling. Also, all the students receive free licenses for the most recent version of the software development environment. In the most recent analysis of the program deployment the LabVIEW academy program at UPB had 312 students enrolled. In the four years, the total number of students coming into contact to this modern and effective form of teaching virtual instrumentation has been 1115, with a slightly increasing trend, mostly due to variations in enrolment numbers. Figure 2 graphically depicts this development.

NUMBER OF STUDENTS INVOLVED IN THE PROGRAM AND COURSE AFFILIATION

Course Name	2010/2011	2011/2012	2012/2013	2013/2014
Automatic Control 3rd Yr.	216	192	222	233
Master AII	26	21	25	24
Mechanical Eng. 3rd Yr.	0	42	59	55
Total	**242**	**255**	**306**	**312**

Student feedback is collected to provide an anonymous evaluation by the primary beneficiaries of these collaborations. This can help improving the course content and teaching style and identify problems in early stage. The feedback form is standardized across the faculty and is applicable to courses from across the various specializations. At the moment the feedback form for the courses is optional but students are actively encouraged to participate in large numbers. Over the time of the implementation the form questions have been slightly modified but the basic idea has remained the same. Topics for feedback related to the practical activities cover: clarity of presentation, efficient, time usage, the behavior of the teaching assistant/instructor, the quality of course documentation, the hardware and software endowment of the laboratory, and general evaluation. In this context, aggregated feedback numbers have ranged between 85-95%. The quantitative scoring is associated with a free text input box where the overall opinion was very positive and encouragement to continue of this path. These are also influenced but other factors outside the implementation of the LabVIEW Academy but we have strong reasons to believe that the program has been an important factor to increase student awareness for opportunities of professional development in their field of study. Feedback participation is constantly increasing from one academic year to another as students become aware that their opinions can lead to a direct or indirect improvement of the academic process outcome. These positive developments also bring benefits at the department and faculty levels, bringing additional visibility and a positive outlook towards industry-academia collaboration success stories.

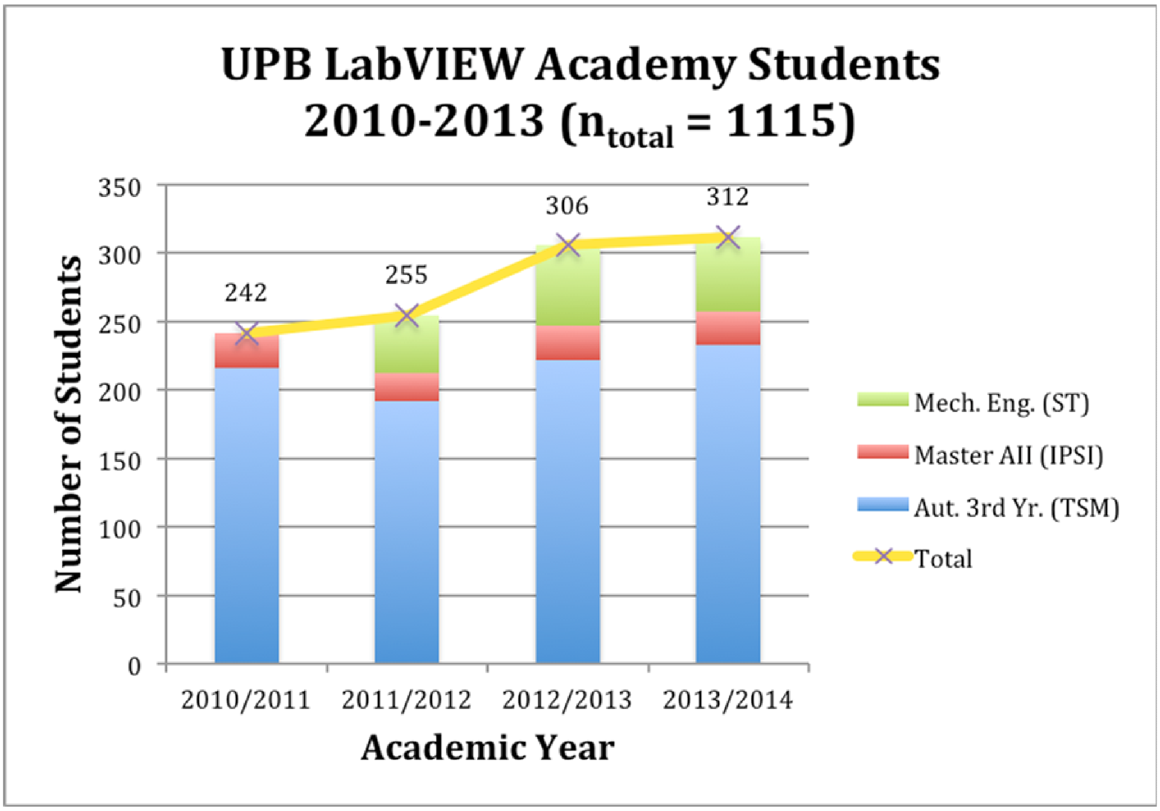

Figure 2. LabVIEW Academy at UPB – Participating Students

IV. CERTIFICATION AS A VALID STEP TOWARDS PROFESSIONAL ACHIEVEMENT

In the industry, IT certifications are seen of a validated path towards professional development and career opportunities. These range from basic and broad subjects to more advanced and narrow ones, and are structured on multiple levels with each superior level having prerequisites the lower levels. Well-known certification programs are lead by Cisco, Microsoft, Oracle, etc. Due to the highly dynamic nature of the field most certifications have a limited validity period with recertification every 2-3 years. Large corporations also use this as a tool in promoting and establishing their proprietary technologies and customer education. Within this context, we have leveraged the feature of the LabVIEW Academy program to provide the students with a free certification exam at the basic level for virtual system development – Certified LabVIEW Associate Developer (CLAD). Subsequent certifications offered by the NI company are at the developer and architect level, which are more complex and require practical development experience with real complex projects. As an important component which helps emphasize the and reward those students which are able to prove significant achievement, it has become a stepping-stone of the LabVIEW Academy deployment. The certification is open to all the students of the Faculty of Automatic Control and Computers from all study groups: bachelor, master and PhD but it is mostly relevant to the ones having recently passed the related courses that were described in the previous section. The examination has been held at the middle of February over the last four years, this corresponds to the first didactic week of the summer semester. It allows the students time for individual study after the winter examination period and is placed in order to maximize attendance.

Figure 3 illustrates the numbers behind the outcome of this certification initiative at UPB. The five categories that are listed include: enrolment, preset, absent, passed and passing rate. Most important lessons that we have learned through this activity that student engagement and enthusiasm follow a well-defined curve with high values at the beginning, a through in the middle and for some a revival at the end.

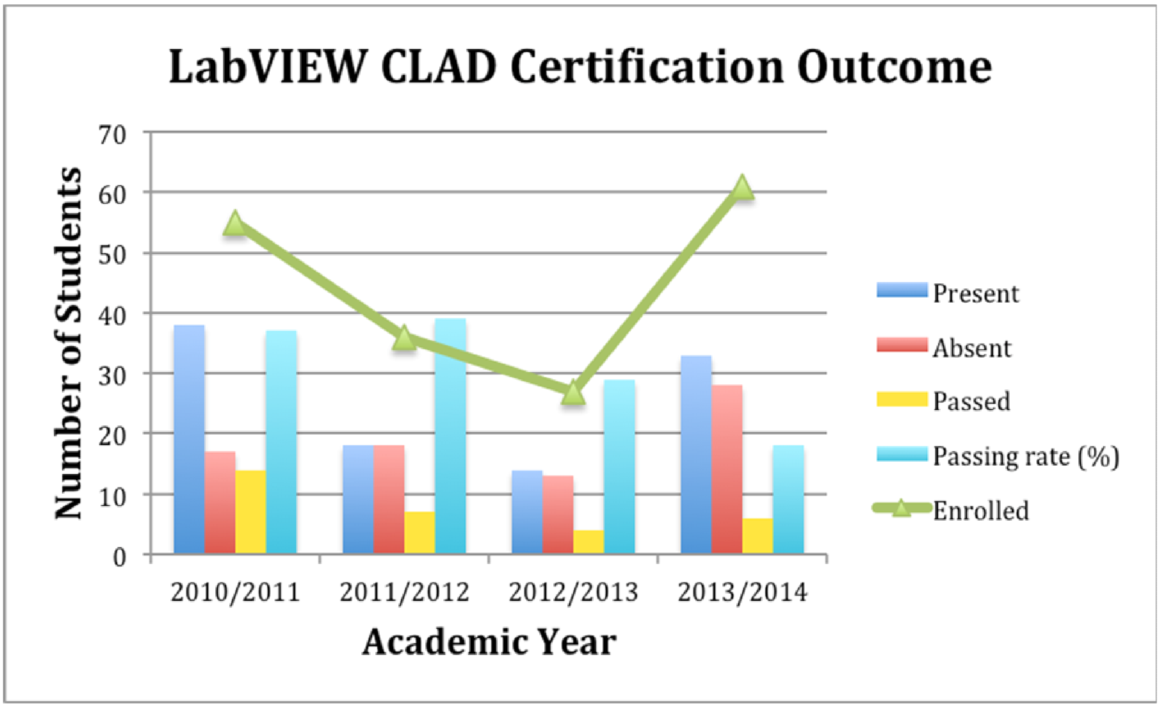

Figure 3. LabVIEW Academy at UPB – Optional CLAD Certification Exam

Testing procedure is administered by the academic staff of the laboratory. The students have a period of around two months between December and January to pre-register their intent to attend the certification through a customized web form and provide personal information such as: name, group, e-mail and phone number. Upon deadline expiration the course responsible person consolidates the data for the final registration the participants to a given day and timeslot through an on-line form with the NI representative office. The students receive the registration confirmation via e-mail along with the personal username and password. The exam and delivered on a web-connected PC with a dedicated software client running on it and under instructor supervision. The testing client is designed not to allow the candidate to switch applications during the test. The testing platform generates a customized test for each participant extracting questions from a questions bank according to a given topic structure. The test consists of 40 questions with a minimum passing score of 28 correct answers, corresponding to a score of 70%. Questions are either single option or multiple option, with the latter being clearly marked. The test duration is 60 minutes and a detailed report is provided at the end to the candidate. Some advantages of this procedure include the fact that they are immediately notified of their score and general outcome. The successful candidates receive their certificate and are entered in an on-line public database with all LabVIEW certified developers worldwide. From there, relevant companies working with these technologies can access a pool of qualified candidates for open positions that they need to fill for project-based and design work in the fields of measurement and automation systems for various applications.

CONCLUSIONS

After four years of implementing the LabVIEW Academy program for virtual instrumentation teaching and certification, it can be stated that the initiative was well received and has enjoyed success. We also consider that the real benefits of the program have been underlined by the strong interest manifested by the students. This has lead to them using graphical system design and virtual instrumentation for subsequent projects during their studies, e.g. control engineering topics using dedicated software packages, the final year projects and master's thesis. The common promotion efforts from industry and academia have become also an impulse to actively get the students involved in other workshops, courses and online seminars outside the core study program, which focus on virtual instrumentation and data acquisition systems. Among the most important lessons learned were that in order to attract and engage students the course content and teaching method has to be challenging, stimulate competition through recognition and/or small rewards and highlight the novelty of the subjects and their relevance in a broader context of professional development.

Perspectives for future development include and up-to-date curriculum and constant updates through new technology. Also, a better promotion of virtual instrumentation specialists among the industry branches using this solutions e.g. by facilitating internships in companies that are involved in this field is sought. The participation and passing rate in the Certified LabVIEW Associate Developer exam should be increased by mentoring students and tracking their progress in individual learning with the provided technical course content and evaluation. Subsequently they should be encouraged to take on the upper levels of certification in the field, only after gaining additional experience with real world projects, including the CLD and CLA. An indicator of achievement can be represented by student involvement in competitions and workshops, which encourage the use of the LabVIEW environment. One example being the LabVIEW Ambassadors program designed by the National Instruments to recruit student representatives for this technology in order to disseminate technical courses to a broader audience within the university or an academic community.

Acknowledgements

Timely and constant technical support from the National Instruments Corporation and the Faculty of Automatic Control and Computers is gratefully acknowledged.

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