

## Project-based learning in programming classes – the effect of open project scope on student motivation and learning outcome

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**Abstract:** In this paper we report on the use of project-based learning in teaching a second-year course in Electrical Engineering that comprises learning to program in LabVIEW – a graphical programming language – and a basic introduction to data communication and telecommunication. The introduction of open project scope has led to higher student motivation and improved learning outcome. In addition, the inclusion of laboratory exercises that provide further tools for interfacing with external hardware, for example Arduino boards, sensors, and wireless networks, has led to further improvement in project quality as students incorporate resources from their own interests and from other courses in their projects.

**Keywords:** *project-based learning, programming, LabVIEW, motivation, learning outcome*

### 1. INTRODUCTION

This paper gives an account of the use of a combination of lectures, PC-based exercises, laboratory exercises and project-based learning for the teaching of a programming and control engineering subject. The insight presented here is based on the past three years of teaching a second-year course in Electrical Engineering called “PC-based instrumentation and communication networks”. The course comprises learning to program in LabVIEW (Bishop, 2010) – a graphical programming language developed by National Instruments – together with a basic introduction to data communication networks and telecommunications.

The insight presented here is based on the authors observations, student evaluations, project quality assessments and exam results. These are used as indicators to assess learning outcome during the past three years the course has been taught by the authors. In this period, the authors have introduced two main changes to the course in an attempt to increase motivation as well as attain to a larger extent hands-on experience-based learning.

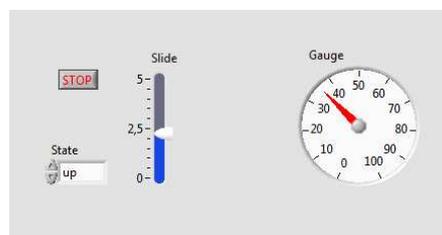
The paper is organised as follows. In section 2 we give an overview of the course with reference to the year 1 of the three-year observation period. Section 3 presents the changes that were made in year 2 and section 4 the changes introduced in year 3 of the observation period together with their effect. In section 5 we discuss these further and interpret the effect on motivation and learning outcome. Finally, we provide some thoughts for further work.

### 2. COURSE OVERVIEW

#### 2.1 Course overview – 1st year of observation period

LabVIEW is a graphical programming language that is originally developed as a laboratory control system but has evolved to become a powerful and versatile environment for real-life control systems and industrial applications. Each program, called a virtual instrument (VI), comprises two

a)



b)

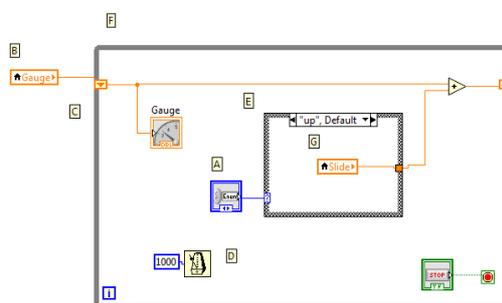


Fig. 1. Front panel (a) and Block diagram (b) of a simple LabVIEW program. The program makes Gauge move upwards or downwards depending on State, at a pace given by the value of Slide. Gauge can also wait. The program is stopped by button STOP.

parts: the block diagram that is the actual logic of the program, and a front panel that is the user interface when the program is run. The front panel is a virtual representation of an instrument as LabVIEW was originally created for the remote control of instruments, among other things. Figure 1 shows an example of a simple LabVIEW program for illustration purposes.

The graphical interface is intuitive and although a rather advanced programming environment can be created based on the LabVIEW platform, the threshold for building a simple control system is relatively low.

The graphical interface appears to appeal also to students that are not especially enthusiastic about programming to begin with. These students that may not be particularly inclined to abstraction tasks, seem to be assisted by the visual interface of LabVIEW. The relative ease of getting started and getting to write simple programs, combined with the immediate result via the front panel, apparently lead to an experience of mastery. This in turn apparently provides a positive feedback mechanism that increases self-confidence and encourages the students to continue their efforts and improve their knowledge and skills. Biggs and Tang (2007) underline also the importance of student motivation, expectations of success and alignment with intended learning outcome. In this regard, LabVIEW is a useful tool for attaining relatively good programming skills also for the less gifted/ less enthusiastic among students.

This part of the course is taught as follows. Each student has two hours of LabVIEW teaching a week in a data-classroom where the student works on a dedicated work-station. The teacher introduces new structures and functions in plenum. Typically, this may require about half an hour in total. Thereafter the students work with exercises and get assistance from the teacher when required. The class is divided in groups so that there are maximum 30, typically 20, students per such teaching round.

In addition, students have laboratory exercises that include hardware components. Laboratory exercises are carried out in pairs of two students and are supervised by an experienced engineer. Laboratory protocols are delivered on completion of the exercise.

Finally, the last four weeks of term, the students work on a LabVIEW project in groups of two. This is presented in further detail below, at the end of this section.

The course comprises also an introduction to data communications and telecommunication. For this part we use weekly lectures in an amphitheatre and include some exercises the students can complete later as voluntary homework. In addition, there are laboratory exercises the students carry out in groups of two supervised by an experienced engineer. In the same way as for LabVIEW, laboratory protocols are delivered on completion of each exercise.

The first years the authors taught this course, the data communication part focused primarily on the Applications layer, Transport layer, Network layer and Link layer. In

addition, there was a good introduction on standardisation work. The laboratory exercises were in accordance with this focus and included one exercise with a web server and web client and communication using HTTP, one exercise on DHCP server, routing protocols and IP addressing, and one TCP/IP exercise.

TCP/IP communication is also implemented in LabVIEW exercises (Reynders and Wright). In particular, information is exchanged between a server program where a certain operation is carried out and a client program from where the user can both monitor the progress and control the operation of the server.

During the last four weeks of term all lectures and laboratories in the course have been already completed and the students can focus on their project. In previous years as well as during the first year of the three-year period this survey refers to, the students were presented with five different projects to choose from. Several of these included external hardware that is controlled by LabVIEW while two of the proposed projects did not include hardware. With one exception, the projects require a client-server architecture.

All lab exercises need to be completed and the project work needs to be completed and approved in order to be eligible for the final written examination. The written examination includes 50% LabVIEW and 50% data communication exercises. The written exam counts for 70% of the final mark while the marks attained from the project count for the remaining 30%.

## 2.2 Student evaluation after year 1 of observation period

Student evaluation at the end of year 1 of the observation period revealed the following. The students were pleased with the LabVIEW part of the course. They appreciated in particular the project work at the end of the course and felt they actually learned LabVIEW during this four-week project period. They thought the labs were good and useful. The data communication part of the course received less enthusiastic comments. Students considered it a “dry” subject they needed to command in order to get good marks, but had relatively low motivation to learn otherwise.

Several of the top students that were the first to complete all LabVIEW exercises at the data class sessions, wished for further exercises and more challenging problems they could work on after class. In addition, several of mainly the same students proposed that project topics were open for the students to define themselves rather than having to choose among the given alternatives.

## 3. CHANGES INTRODUCED IN YEAR 2

### 3.1 Changes introduced in year 2 of the observation period

In response to the evaluation and proposed modifications by our students, we introduced the following changes in year 2 of the observation period.

i. The list of exercises that are given in each of the data class sessions of LabVIEW was enhanced to include several extra exercises the students can work on if they wish to. These are voluntary so that the less motivated among students can focus on learning basic skills while the more motivated/ gifted students can challenge themselves, gain experience and improve their level of understanding.

ii. The data communication part of the course was modified as follows. Standardisation related work was in practice removed apart from a short introduction. In its place we have introduced to a larger extent Layer 2 and Layer 1 material. These include among others wireless networks and optical networks.

iii. The third and most important change that year was that we opened for projects where the scope is defined by the students. The way this is implemented is that the students need to send an email with a short description of the project they wish to carry out – typically one paragraph. They then receive comments and suggestions and get it approved by the teacher prior to project start.

### 3.2 Student response after year 2 of the observation period

Student evaluation at the end of year 2 of the observation period revealed the following. The students were still pleased with the LabVIEW part of the course. They appreciated lab work and in particular the project work, like in year 1. The data communication part of the course was still less favoured and the topic was still described as “dry”.

Note that the course we refer to is offered to students that specialise on Automation or students that specialise on Medical Technology. On the contrary, students that specialise on Communications perceive a similar course on communication only, i.e. without LabVIEW, as “fun”. This can be attributed to the initial interest of these latter students on the subject of communications. However, in our opinion the low motivation of the Automation and Medical Technology students on this subject may stem from their limited understanding of the subject and the subsequent fact that they do not attain a good enough level to be able to implement this material in their projects and see the potential usefulness of it.

The most marked effect was on the quality of the projects. Here students incorporated external hardware and demonstrated quite advanced projects, among others in areas of their own interest. This is further discussed in section 5.

## 4. CHANGES INTRODUCED IN YEAR 3

### 4.1 Changes introduced in year 3 of the observation period

Encouraged by the evaluation and response from our students, we continued on the same line and introduced the following changes in year 3 of the observation period.

i. The web-server related laboratory exercise was replaced by a wireless sensor network that uses Zigbee Xbee and Arduino. LabView is used for sensor data logging and user interface.

ii. The curriculum of the data communications part of the course was changed somewhat in that the part on wireless networks was extended. In addition, there was some increased focus on security.

### 4.2 Student response after year 3 of observation period

Student evaluation at the end of year 3 of the observation period revealed the following. The students were equally pleased with the LabVIEW part of the course. They appreciated lab work, if with some suggestions for improvements. These concerned in particular better alignment between the lecture material and the network laboratory exercises and can be interpreted as a result of the fact that the changes to the lab exercises were somewhat new and there is still room for improvements. The students appreciated in particular project work. Some of the comments point towards extended project work.

The most marked effect was again on the quality of the projects. Some of the students incorporated external hardware, including Arduino boards and LEGO robots. In addition, a couple of the projects incorporated wireless communication between the external equipment and the LabVIEW control or the Arduino board, etc. In total the project quality was improved. This is further discussed in section 5.

The written exams and actual final marks were not significantly improved. This is discussed in the next section. At the same time, and based on the student evaluation, there has been a gradual improvement of the students own evaluation of their learning outcome. This summarised in Table 1 below. The number of students that participated in the evaluation is relatively low, so the results are clearly indicative.

**Table 1. Number of students that are satisfied with own knowledge (total answers)**

Observation year	LabVIEW	Datacom	
		Number	Percentage
1	20 (20)	10 (20)	50%
2	21 (21)	15 (21)	71%
3	31 (31)	23 (31)	74%

## 5. DISCUSSION

### 5.1 Student evaluation – responsibility and insight

One of the authors who was a new-baked teacher at the beginning of the observation period was pleasantly surprised when her students proposed more homework throughout

term. The general expectation is that students want to do as little as possible to receive their degree. This was, however, by no means the case here and has in our experience not been the case in general, in any case not for the average student and above. Students take responsibility for their own learning and knowledge. When they are asked to come with suggestions they show in our experience high level of responsibility, great insight in learning processes and a lot of learning enthusiasm. This in turn increases our motivation and our enthusiasm and dedication to teaching.

### 5.2 Examination results

It is not easy to deduce any clear information regarding the knowledge level attained by the class based on the results of the written examination. These are shown in Fig. 2 below. Here we show the point score distribution at the written examination for each observation year. This accounted for 70% of the final mark, whereas the remaining 30% was determined by the project, as mentioned earlier.

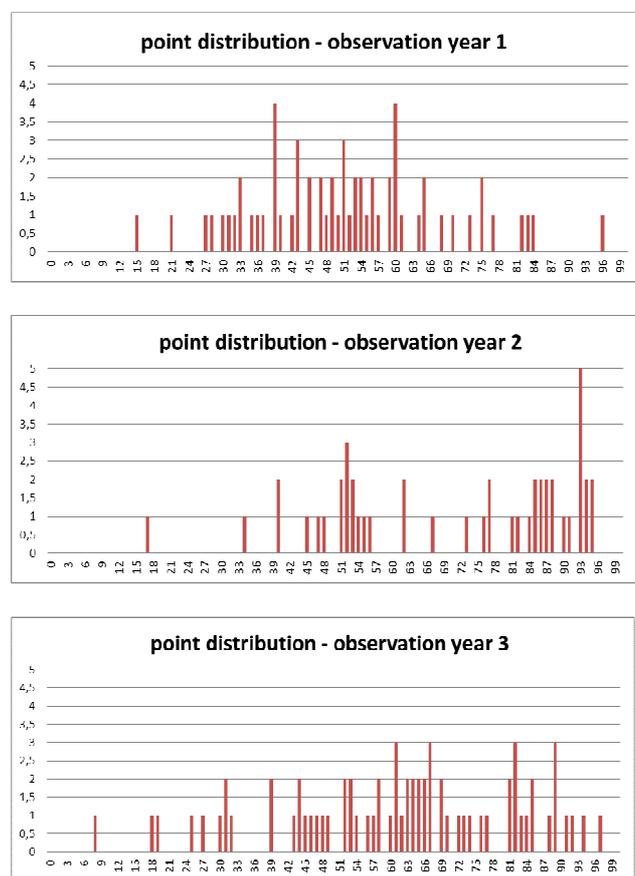


Fig. 2. Distribution of points attained at the written examination (max attainable points: 100) for the entire class for the three observation years.

The point distributions indicated that the difficulty of the examination may have been somewhat lower during year 2 of the observation period. The letter-mark (A-F) the student obtained for the written examination was subsequently

somewhat adjusted with respect to the normative distribution of the class to reflect the difficulty of the examination.

### 5.3 Project-based learning

The first year of the observation period the class comprised many highly motivated students that appreciated programming to begin with. These students were forced to choose one of the five project models that were available at the time. The students' creativity was channelled towards adding several finesses in their programs and the overall level of the projects was very high. There was however some frustration over the limited project scope available.

Opening for self-defined projects in year 2 of the observation period made it possible for students to incorporate their own interests into the projects and to make use of resources they had outside the course, for example based on their own interests and hobbies or based on work they had done in other courses. Examples are a) a project where LabVIEW was used to create an interactive DJ music server that was connected to a professional music system, b) a project where vital data were collected from a set of body sensors and ambient sensors at an (imaginary) patient's home, analysed, stored, and forwarded together with alarms to doctors and nurses as required, c) a LabVIEW program for the remote control of an actual laboratory water-tank system. The students were proud of their projects and put a lot of additional effort to add all sorts of finesses and extra features. Motivation was clearly higher than the preceding year and the reported experience of "fun" was very high. The general marks attained from the LabVIEW part of the written examination were also improved. We considered this a success. It is also worth noting that not only top students were involved in these self-defined projects. Another important aspect is that the ambition level of these projects is typically significantly higher than the five original project models.

The inclusion of a laboratory exercise with a wireless sensor network and use of Arduino in year 3 of the observation period, has led to what we consider a further improvement of the project work. Several of the projects incorporated control of external hardware and some projects used wireless network communication. Examples are a) a LabVIEW-controlled LEGO robot system for sorting garbage and recirculation, b) an actual alarm system with optical sensors controlled via LabVIEW realised using Arduino, c) a "home-made" toy robot with a series of sensors/ actuators on Arduino boards controlled via LabVIEW. In many cases the students exceeded the total number of hours that are required for the project and described again the project as great "fun". In total, the students have impressed us with their zest, creativity, and ability to combine available resources and learn by doing.

The effect of project work on learning outcome cannot be emphasised enough. This is in accordance with other studies (Blumenfeld *et al.*, 1991). Biggs and Tang (2007) underline also the importance of student motivation, expectations of success and alignment of teaching methods with intended learning outcome.

In our experience, project work has been the highlight of the whole course. In fact, several of the students have perceived project work as a sort of reward for their learning efforts throughout term. This has been the case especially after we introduced open project scope for the projects in this course.

#### 5.4 Further work

In our opinion the low motivation of the Automation and Medical Technology students on the data communications part of the course stems from their limited understanding of the subject and the subsequent fact that they do not attain a good enough level to be able to implement this material in projects and see the potential usefulness of it. Our first introduction of more hands-on type of network laboratory exercises with focus on wireless networks has been successful in that it has triggered some implementation of wireless remote control in the project work. We intend to improve this further by introducing further laboratory exercises and incorporating further sensor and actuator-based exercises in the future.

The changes introduced during the three years presented here show in our opinion an encouraging improvement of learning outcome and learning zest. In collaboration with the lecturers of other courses, e.g. electronics and C-language programming, some of which are taught in parallel and some of which are taught prior to the course presented here, we intend to introduce further tools that can be potentially introduced in the projects of our course. These include external data acquisition kits owned by each student, introduction of Arduino programming – and corresponding projects – together with electronics classes, and more. These will hopefully create further synergies between the courses through our curriculum, increase the quality of the studies and of the overall learning outcome.

The authors would like to thank our colleagues Hilde Hemmer, Tore Øfsdahl and Harald Hofseter for their valuable contribution. Last but not least, we wish to thank our students whose zest for learning is a continuous source of inspiration for us.

#### REFERENCES

- Bishop, R. H. in: *Learning with LabVIEW 2009*. National Instruments. Pearson Education, New Jersey, 2010.
- Biggs, J. and Tang C. in: *Teaching for quality learning at University*. Third Edition. The Society for Research into Higher Education. Open University Press. McGraw – Hill Education, New York, 2007.
- Blumenfeld, P. C. *et al.* (1991). Motivating project based learning – sustaining the doing, supporting the learning. *Educational Psychologist*, **Volume 26**, page 369-398.
- Reynders, D. and Wright E. in: *Practical TCP/IP and Ethernet Networking*. Newnes, Elsevier, Oxford.