HOT WHEELS® AND LABVIEW MEET AT NHRA DIVISION 1

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1. INTRODUCTION

Integration of engineering design experiences into first-year introduction to engineering courses is an important and challenging task, as we try to keep the activities from becoming stale and repetitious, while at the same time keeping the projects at an appropriate level for these new college students and attempting to retain these students in the engineering majors. Tanyel (2005) reflected on an initial trial of teaching LabVIEW in the EGR101 class at Geneva College. His recommendations for future revisions to this course included revision of the notes/text which he authored for the course, more sessions taught in the computer laboratory, more use of Blackboard for virtual classroom work, and including other engineering faculty in the design projects.

The first author had taught EGR101 for the previous six years, and returned to teaching this course in Fall 2005. It was deemed desirable to continue the LabVIEW component of the course and to create design projects which required the students to apply the LabVIEW concepts they would learn during the computer lab sessions. This decision was based on the recommendations listed above, plus specific student comments on the end-of-course survey asking for "more complicated tasks" using LabVIEW and a general feeling of student confidence in the use of LabVIEW which seemed desirable to reinforce. The new project component is also consistent with recommendations by Burton and White (1999). They concluded that projects and computing tools should contribute to student interest and success in a freshman design course. These conclusions were based on surveys of freshman and senior students at University of Alaska Fairbanks.

The authors brainstormed for ideas that would be feasible within the context of the course and the available resources at the college and generated three possible design projects. These were

1. Neuroscience measurements for undergraduate biology laboratories (Wyttenbach, 1999)
2. Athletic performance measurements, in cooperation with the physical education/track and sports management faculty
3. A measurement/control system using Hot Wheels cars

The third option may seem a bit unusual, but it should be noted that another key feature of EGR101 as taught in 2004 was the use of Hot Wheels cars as incentives (Tanyel, 2005). In considering these options, the following conclusions were reached.

- Project #1 was not suitable for first-year students, but might be a good application for junior or senior students as we establish a core of LabVIEW competency.

- Project #2 was not well-defined, and the equipment needed could become too expensive for a large class.
- Project #3 seemed manageable from a cost and equipment point of view, and would also maintain some of the fun elements previously incorporated in the course.

It also became clear that with a record enrollment in EGR101 we needed to keep the project component manageable, so we chose the third option, which will be explained in detail below.

This goal of this paper is to test the following hypothesis. ***Use of LabVIEW for a real, physical task will improve the students' grasp of LabVIEW.*** Survey results from the class as conducted in 2004 and as modified in 2005 will be used to test this hypothesis.

2. COURSE DESCRIPTION

2.1 General Course Structure and Content

EGR 101 is an introductory course taken by all students in the engineering program at Geneva College, including those in the Civil, Computer, Electrical and Mechanical engineering concentrations of the ABET accredited BSE and students in the separate Chemical Engineering major. It is also taken by a few non-majors from departments such as Applied Math, Math Education, and Business.

The Geneva College catalogue describes EGR 101 as follows:

> Introduction to engineering design and decision-making. Christian world-view applied to engineering. Use of logic, experimental data and design criteria. Project-oriented. First semester.

The objectives of the course listed in the syllabus include:

2. To develop a peer network to enhance [the students'] academic success.
3. To introduce [the students] to the engineering design process.
4. To develop and guide [the students'] creativity in the context of engineering design.
5. To introduce [the students] to the civil, mechanical, and electrical engineering professions and the associated professional organizations.
6. To develop an awareness of the current technical challenges and advances at the frontiers of engineering.
8. To learn how to work effectively as a team member.
9. To develop skills such as time management, study groups, and study techniques.
10. To understand and develop good communication skills (graphical, written, and oral) and recognize their importance in engineering.
11. To introduce selected topics in engineering science as related to specific design and research projects.

12. To develop skills in locating information resources (library and other).
13. To introduce some of the computer tools and laboratory equipment available in the department.

Most of these objectives are intended to be achieved at the introductory level, with reinforcement in later courses in the engineering core and in the specific disciplines. The course is centered around the five step design process presented in Voland (2004), which is the main textbook. The design project is intended to provide experience in applying this design method to a realistic engineering problem, as well as the development of teamwork and communication skills. Past projects have included design of a human powered pump (Dally, 2000), design (using FEA while teaming with senior students) and testing of structural elements (Shaw and Harwood, 2002), and design projects based on ASME competitions (ASME, 2006) as well as the use of mechanical dissection (reverse engineering) to teach design (Beaudoin and Ollis, 1995).

2.2 LabVIEW textbook and course structure

The outline of the six lessons used to teach LabVIEW basics and the associated electronic text is described in some detail by Tanyel (2005). EGR101 meets twice weekly for one hour lectures and once weekly for a 3 hour laboratory period. This gives 14 laboratory periods completely dedicated to project work. Professor Tanyel was the lead instructor for the six LabVIEW lessons, with Professor Shaw and two senior students assisting during the computer exercises. Since the class enrollment was 49 students, the hands-on portion of the LabVIEW instruction occurred in two adjacent classrooms. During these six weeks the class met for one hour in a large lecture hall, where the LabVIEW material was introduced and demonstrated by projection from the instructor's computer. During the final two hours of the period students worked on structured assignments to reinforce the LabVIEW concepts. This was done during weeks 1 and 3-7 of the course. Week 2 was used for team building activities directed by the experiential learning department at the college. The remaining weeks of the semester focused on the Hot Wheels Drag Racing project, as will be described separately. The students were assigned to groups for project work. These groups were assigned before the Week 2 team-building activity, so the students could get to know and work with each other early in the semester. Students were assigned to ten groups of four or five students each using 2 basic guidelines.

1. Goal of a broad distribution of concentrations within each group – the "ideal" group would include one each of civil, electrical/computer, and mechanical concentration plus one or two additional students.
2. Gender mix – Assign at least two females to any group with female members so female students would not be isolated.

Other aspects considered informally during group selection included placing at least one enthusiastic (based on classroom participation) member in each group, and attempting to achieve a good blend of commuter and resident students in each group (noting that the class was made up of approximately 75% resident students).

3. PROJECT DESCRIPTION

The problem statement distributed to the student groups is quoted here.

Hot Wheels Drag Racing Timing and Control System

It has been determined that there is a market for an automated timing system for Hot Wheels drag racing on gravity tracks. Design, build and demonstrate a system to meet the following specific requirements:

1) Design a system to release the two vehicles at times determined by a trigger (throttle) input from a human operator (driver).
2) Design a "Christmas Tree" to let the drivers know when it is legal to release the vehicle and whether they have red-lighted. Use a "Pro Tree" timing sequence for this (see www.nhra.com/basics/basics.html for drag racing rules and terminology). Include the capability to hold a handicapped race.
3) Design a timing system to measure elapsed time and vehicle speed. Vehicle speed will be based on a 66 ft (to scale) trap area.
4) The system must be easily attached to the Hot Wheels track without damaging it. Maximum assembly time will be 5 minutes.
5) The complete system must fit within a 16x16x32 cm box before assembly and/or placement. The system must be assembled from the box, if assembly is required, and put in place within the allowed 5 minutes.
6) Systems will be evaluated for accuracy, ease of use, aesthetics of both the hardware and the software, and creativity.
7) An optional (extra credit) weigh-in procedure may be added using a digital balance which has RS-232 communication capabilities.

Allowable resources and materials.

Measurement Computing model USB 1208 data acquisition module with 8 analog inputs, 2 analog outputs, and 16 digital inputs/outputs.

LabVIEW and computer with USB port

Electronic components from a list to be supplied by the instructor. They will include

- Light emitting diodes (LED's) in red, green, and yellow
- Infrared LED's and phototransistors (detectors)
- Buffers for digital outputs
- Signal conditioning for digital inputs
- Switches (SPST)
- Battery compartments (AA) and/or connectors (9 volt)

Mechanical components

- To be determined

The instructor will entertain requests for additional materials on an as-needed basis. A public discussion forum will be established on Blackboard to deal with questions related to the rules (clarifications, interpretations, modifications).

Reporting and Documentation

All work on this project must be clearly documented in your lab notebooks. You may reference material from other members of your team by name and page number to avoid duplication of effort.

Reporting will consist of a mid-project progress report (oral and written) and a final design report, including evaluation of actual performance of the system.

The students had six weeks to work on this project, with the seventh (final) lab period dedicated to testing their systems in a public forum. Hands-on learning techniques to familiarize them with the data acquisition hardware and with basic circuit elements such as LED's, phototransistors, and buffers, and voltage regulators were incorporated into the first three weeks of this period. The final report was due 5 days after the final testing, after encouraging students to draw conclusions and make recommendations for future work based on the results of their testing.

4. RESULTS

It is not surprising that the students, as well as the instructional team, found the timetable for this project a bit overwhelming. As we pressed on there were many times when we wished for a "restart" button for the semester. As the project progressed we realized that it would have been a good idea to introduce some of the material on electronics earlier in the semester while delaying some of the LabVIEW coverage.

It also became clear that the project was rather ambitious. Since most of the student groups had initially focused on the timing and logic for their LabVIEW code, we decided to simplify the project by building a standardized release mechanism using solenoids. This had the desired result of simplifying the project, but also had some unintended consequences. Two of the ten student teams had made a significant time investment in prototyping release mechanisms. One of the groups became rather frustrated and felt they had wasted their time, while the other group asked if they would still be allowed to use their release mechanism. The second group was one of the more successful, including having one of the best reports that the first author has seen in seven years of teaching this course.

Figure 1 shows the basic elements at the starting end of the track. The two cars are being held in place by solenoids. The box on the right side with screw terminal connectors is the digital IO board, the breadboards in the foreground are the electronics for buffering digital IO and driving the LED's and release mechanisms, and the structure above the cars between the tracks is this group's Christmas tree. Figure 2 illustrates two cars passing through the timing trap, which is scaled to match the 66 foot length of those in the NHRA.

4.1 End of Course Student Surveys

A survey was used to solicit student evaluations of the course. A set of question covering three main focus areas was distributed and collected on the last day of class, with a 96% response rate. Some of the questions focusing on LabVIEW and the design project were selected from a survey used in the 2004 offering of the class, which included LabVIEW instruction, but not a LabVIEW based design project. The repeated questions can be seen in Table 1.

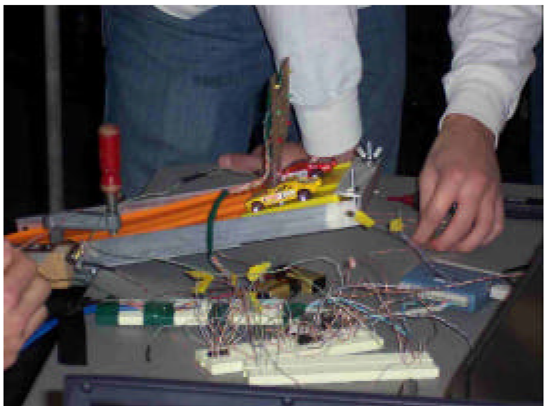

Figure 1. Release mechanism, electronics, and digital IO board.

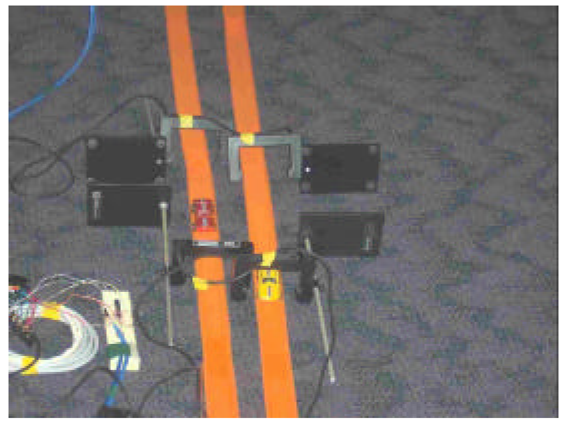

Figure 2. Two cars passing through the timing trap.

Statement	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
I enjoy working with computers.	20	8.9	6.7	20	20	22.2	20	24.4	33.3	24.4
Before starting EGR 101, I enjoyed programming. *	53.3	64.4	6.7	8.9	20	17.8	13.3	8.9	6.7	4.4.
Now that I've had an introduction to LabVIEW, I enjoy graphical programming.	6.7	26.7	6.7	31.1	33.3	17.8	53.3	15.6	0	8.9
I feel confident that I can program simple engineering/scientific problems in LabVIEW.	0	6.7	13.3	29	13.3	31.1	73.3	22.2	0	15.6
I appreciated the exposure to LabVIEW.	0	17.8	0	17.8	13.3	26.7	60	17.8	26.7	22.2
I wish the LabVIEW sessions were every week, rather than every other week.	13.3		6.7		46.7		20		13.3	
I wish we could learn more features of LabVIEW ...	13.3		6.7		13.3		60		6.7	

Table 1: Percentage responses to questions on LabVIEW. The first percentage is for the 2004 class, while the second is for the 2005 class. Note that the final two questions were not asked in 2005, since we had fulfilled this wish by introduction of the new design project.

Based on a Chi-square test, there was no significant difference (α=0.05) between the responses of the groups to the first two questions. There was, however, significant difference between responses to the next three questions. This would indicate that with the new design project the students enjoy LabVIEW less, feel less confident in their abilities to program for real problems, and had less appreciation for the instruction in LabVIEW.

Student comments centered on the idea of doing a better job of connecting the LabVIEW content to the project tasks. They asked for "more connection between lectures and the project", " better definition of the project". One student commented that the "6 week prep course was. … scattered and not connected.." to the project.

4.2 Evaluation of Projects

A major goal of EGR101 is to teach the engineering design process, so evaluation includes many aspects beyond the performance of the final product. Of the ten student groups, only one was fully successful, as demonstrated by releasing cars for several races and accurately measuring times. Other groups had varying degrees of success, with the biggest obstacles to success being dealing appropriately with the release timing of a handicapped race, inadequate understanding of the use of transistors to energize the release solenoids, and poor understanding of the need to have the release switch appropriately referenced to ground.

Most groups had a well-designed user interface, which was not surprising, since they had practiced this in the LabVIEW portion of the course. As shown in Figure 1, most groups were still in the middle of truly figuring out the circuits necessary to condition input and output signals, which led to the standard problems of unreliable breadboards.

The final design reports varied in quality, and the quality of the report was not necessarily correlated with the quality of the hardware and software. This is important to note, since part of the learning process in this course is to learn how the design process *should* work, which is sometimes best learned from an apparently failing product.

Some highlights include student use of the rapid prototyping machine to produce components such as the starting switches and Christmas trees. An excellent example of this is shown in Figure 3.

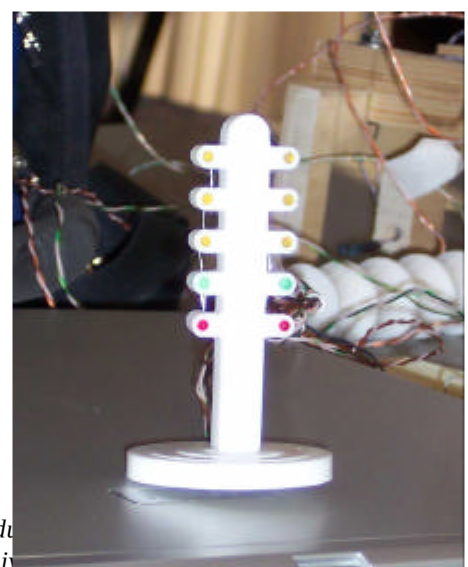

Figure 3. Christmas tree produced using rapid prototyping machine.

4.3 *Evaluation of Group Dynamics*

An end-of-course peer evaluation survey was used to assess group dynamics related to project work. Students were asked to identify leadership roles exercised within the group with respect to organizing meetings, LabVIEW coding, mechanical and electrical hardware construction and testing, and reporting. They were also asked to divide a hypothetical cash bonus between the group members and justify the distribution based on "accomplishments and contributions of each team member." Students also gave an estimate of total out-of-class time spent on the project, both in group activities and individual efforts.

The results of these surveys give a measure of student perception of group dynamics. There is a great consistency within groups for the reported value of total time working as a group and in the division of the "bonus check". Most groups reported approximately 15 hours of group work and approximately 5 hours of individual work outside of the normal Wednesday afternoon lab period over the 7 week duration of this project. There were 4 students who, based on these evaluations, made no substantial contributions to project work outside of class time (and exhibited a similar degree of (non)participation during lab periods, as observed by the instructor).

As expected, the highly successful groups distributed work and responsibility well, and tended to have high quality reports and projects. The group with the best-performing project achieved this mainly through the efforts of a highly motivated electronics hobbyist, but their low-quality written report is consistent with the poorly distributed work-load documented in their peer assessments.

4.4 *General Observations*

It became clear that for most groups one or two students became the LabVIEW experts, with the other students working on things like construction of the "Christmas Tree", timing traps, and other physical objects. The most neglected portion of the project tended to be the electronics. The group with the most success in this area included a student with a great deal of robotics experience. As the day for testing approached it became clear that most groups did not really "believe" that the system could be tested in a modular manner, with the circuitry easily separated from the software and from the digital IO board. This led to late-night panic and long lines of students wanting to test their systems with the digital IO boards when they were not really ready or sure that their circuitry was working.

5. DISCUSSION

The results of the student surveys are consistent with the tendency of the students to designate one or two members of the group, usually those intending to continue in the electrical engineering concentration to be the LabVIEW "experts". This can be seen in student responses to the third and fifth questions in Table 1, as well as in comments on the survey forms indicating their belief that such skills were only important to electrical engineers.

The surveys do not provide evidence to support the hypothesis that this realistic project enhanced the students' grasp of LabVIEW, as measured by their self-perceived ability to "program simple engineering/scientific problems in LabVIEW." This perception may be driven less by actual ability, and more by the real difficulties encountered by the students who were required to work with LabVIEW in a realistic environment. The group of students from 2004 had only done LabVIEW programming in the computer lab, while those in the year 2005 group had to deal with real hardware issues.

Comments from the student surveys and the observations of the instructors also point to the need to more carefully plan the physical aspects of the project and to more carefully integrate instruction in the hardware issues of the design project with the software instruction. In considering this experience it also seems that the level of complexity of timing a handicapped race distracted from the more fundamental tasks related to hardware/software integration.

This new project did add a valuable experience for the students, and they did accomplish many of the design goals, but their perception of the project includes a great amount of frustration, both with the imperfect organization of the material they needed to learn and with the final result.

6. RECOMMENDATIONS

In light of the above results, we have several recommendations for changes to this experience which should lead toward more successful use of a LabVIEW based project in accomplish some of the objectives of EGR101. These include modifications to the project itself, modifications to the instructional approach, and additional lecture and discussion topics related to the relevance of this project to real world design for each of the engineering disciplines.

Project modifications which may help to address some of the concerns noted above include providing some pre-packaged LabVIEW VI's and sub-VI's which could be "purchased" using a predetermined budget of "LabVIEW dollars", with similar options available for the release mechanism and the timing electronics. This would still require the student teams to integrate all of the subsystems for this project, but would let them focus on building a limited number "from scratch". This would help more of them to have fully operational final products and would also help them learn about budgeting issues in engineering design.

Instructional modifications will include more careful integration of LabVIEW instruction with the introductory material on circuits and data acquisition, earlier introduction to the entire project, and more design briefings during the entire fourteen weeks of the semester. Mini-projects which can be used as components of the final design project will replace the current LabVIEW learning modules. The level of increasing difficulty of these projects should build a more solid basis for completion of the final project in a paradigm similar to that used by Wang (2001). This should help make the LabVIEW instruction more relevant, give more time for students to build confidence in learning new material, and give earlier opportunities for intervention if groups are struggling.

Additional lecture and discussion material can be added during the two weekly lecture periods to help students from all disciplines see the relevance of design projects such as this, even if the project *looks like* electrical engineering to them. This might include simple lists of modern computer applications in the various disciplines, such as GIS and smart structures for the civil engineers, feedback and control applications for the mechanical engineers, and automated process control and monitoring equipment for the chemical engineers. It could also include mini-presentations by senior-level students working on design projects which address such issues. This, along with the budget-driven design concepts noted above should at least begin to bridge the gap for students who might not be motivated solely by the challenge of completing the project successfully.

Although this year's modification of our approach to using LabVIEW in the Introduction to Engineering course was not a resounding success, there are certainly lessons to be learned, and it is worth trying to do a better job in this area. The students will be seeing LabVIEW again as they progress through the curriculum, so we will continue to seek the best way to present this material to first-year students in the context of engineering design.

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