A Truly Large Group Project for an Introductory Level Digital Electronics Class

Michael J. Sheliga
Department of Technology
Eastern Kentucky University
Michael.Sheliga@eku.edu

Vigyan Chandra
Department of Technology
Eastern Kentucky University
vigs.chandra@eku.edu

Abstract

Technologists often work in large multi-disciplinary groups where effective communication and teamwork skills are essential. Despite the fact that many employers are looking for employees with such skills assignments that challenge these skills in a truly large group are rare in academic settings. In the introductory level digital electronics course for freshman-level electronics and computer science students at Eastern Kentucky University a large group project is used to simulate real world teamwork and communication difficulties. The proposed project requires a group of five or more students to build a large circuit that would not be possible for a smaller group, allowing to time and resource constraints. The project is scalable to varying group size and can be adjusted for different student audiences by varying the difficulty through depth of class coverage, or by requiring differing technical details. The project includes communication challenges and group decisions that must be made identically for all team members. It also includes decisions that not all group members need to participate in. These conditions are similar to many real world business and technology projects. Results are presented that indicate the percentage of students who make key group decisions and the outcome of each group's project.

Introduction

Large group experiences are a major part of many careers that are not easily simulated in academic settings. Many employers are looking for employees with good communication and teamwork skills, as well as experience with working as part of a large team. Being able to work with those of varying technical skill levels is especially important for technology students. However assignments that challenge these skills in a truly large group are rare in academic settings.

Group projects in academic settings often include small groups of 2 or 3 students. Since communication challenges go up quadratically compared to group size, groups of 6 to 10 impose communication and teamwork challenges that simply do not exist in small groups. A truly large group imposes much more stringent communication and teamwork difficulties on group members which are difficult to simulate in non-large group assignments. The proposed project of an N-bit adder requires students to build a large circuit that would not be possible for a group of only 2 or 3.

This project has several built in features that help to improve student learning. First, the assignment is easily scalable to varying numbers of students by changing the number of bits in the adder. Likewise the assignment can be adjusted for different student audiences by adjusting the difficulty through depth of class coverage or by varying the assignment to include differing number representations, overflow and/or subtraction.

Second, some parts of the lab, such as checking for 2’s complement overflow require the group to implement certain features only once. These features are included in part to increase the difficulty of the assignment and challenge high functioning students, but also to include material that some students may not need to work on. In business settings many members of a group will not be able to know all details of the project. Finally, the assignment can be accomplished during normal laboratory time in only 3 one hour labs.

Third, the project includes several criteria that require students to communicate, make common group decisions and work as a team. First, students are split into groups with those they normally do not work with and are given the assignment 'on the fly' without prior knowledge of what the assignment will be. Second, by choosing an appropriate level of difficulty based upon overall student ability, higher and lowering functioning students are forced to share information. It is desired that a few of the students in each group understand how to complete the entire assignment. These students must then share their technical knowledge for the group to be successful. Third, through varying resources and class discussions the students are presented with a variety of designs for their implementation and are forced to consider, discuss and agree upon a common one. Fourth, since the assignment requires several copies of the same circuit to be built, common implementation details for each 1-bit adder is important.

The paper describes

- Adjustability of Project Criteria and Difficulty for Student Ability and Scalability for Varying Number of Students
- Project Criteria that do Not Impose Communication Constraints and that are Normally Not Understood or Completed by All Group Members
- Project Criteria that Should be Agreed Upon and Done Identically for All Members
- Requirements on Students of Varying Technical Abilities to Share Information and Work as a Team
- Project Criteria Which Impose Communication Challenges Not Easily Experienced Elsewhere

General Description and Adjustability to Student Ability and Group Size

The project chosen is that of an N-bit 2's complement arithmetic unit. Both the number of bits and the complexity of the arithmetic unit have been varied in past semesters. This has been done in order to determine the optimal project size and difficulty so that the project is challenging yet manageable in the allotted time.

All student groups were given three one-hour laboratory periods to complete the project, along with time outside of class. These laboratory periods were normally spaced out over one week. Each group member possessed a kit containing common two-input gates except for exclusive-NORs. The students did not possess mid-scale parts and they did not have multi-input gates. For the first five groups given the project the technical requirements were that:

> You must build and display a four bit 2’s complement half adder (i.e. - no carry in) using only the gates from your kit. Additionally your implementation must indicate if there is overflow.

On the other hand for the last two groups the requirements were modified to:

> You must build and display a six bit 2’s complement half adder-subtractor (i.e. - no carry in) using only the gates from your kit. The input S=1 means subtract, while S=0 means add. Additionally your implementation must indicate if there is overflow. You may receive but not give help from/to others outside your group.

Table 1 shows group information for all groups that have attempted the project. The “Group Name” is an amalgamation of the semester, a student's initials, the group size and the average grade given to the group. The “Project Assigned” column indicates the project assigned to each group where HA indicates a half adder, HAS indicates a half addition-subtraction unit and O/F indicates overflow. Recall that all projects involve 2's complement numbers and hence 2's complement overflow. The “Group Size” is indicated in the third column while the “Portion Completed” column indicates how much of the project the group completed. For example, "All" indicates the entire project was completed while "4 Bit HA No O/F" indicates the group completed the 4-bit half adder but did not account for overflow. Finally the “Classes Taken” column indicates how many classes it took each group to complete the project to the extent indicated in the portion completed column. For example, it only took group Sp05ALDU795 two classes to complete the entire 4-bit half-adder including overflow.

Table 1: Group Size and Completion Status

Group Name	Project Assigned	Group Size	Portion Completed	Classes Taken (3 Maximum)
Sp05ALDU795	4 Bit HA O/F	7	All	2
Sp05STGO865	4 Bit HA O/F	8	2 Bit HA	3
Sp05KMAC880	4 Bit HA O/F	8	4 Bit HA No O/F	3
F05CHWI695	4 Bit HA O/F	6	All	3

Group Name	Project Assigned	Group Size	Portion Completed	Classes Taken (3 Maximum)
F05TRFR685	4 Bit HA O/F	6	4 Bit HA No O/F	3
Sp06ANCU1075	6 Bit HAS O/F	10	2 Bit HA No O/F	3
Sp06TYBR778	5 Bit HAS O/F	7	3 Bit HA No O/F	3

The project can be adjusted for both varying number of students and the level of student ability. While the projects assigned in Table 1 are recommended for the students 'audiences' who have attempted the project, the project difficulty must be adjusted for student ability and background. This can not be stressed enough. What is optimal for one group of students may be much too easy or much too difficult for another group. There are numerous factors that influence apparent project difficulty including but not limited to student problem solving ability, student academic level, time allowed to complete the project, prior instruction on related topics, and assistance given during the project. Each of these should be carefully considered before choosing project difficulty for any particular group of students. These factors are discussed below for the student audience at the authors' university.

There are a number of factors that make the above project challenging for the students who have attempted the group project. Primary among these is the ability of the student audience where the project has been given. Eastern Kentucky University (EKU) is a four year undergraduate university located in East Central Kentucky with an enrollment near 16,000[[1]]. EKU has nearly open admission policies with a minimum ACT score for normal admission of 18 or SAT score of 870 [[2]] and an average ACT score of 19.28 [[3]]. The group project was assigned to students in the freshman level introductory digital electronics class. The vast majority of these students were computer networking or computer science tech students although a few were from other majors. Most of these students are at a very basic mathematical level and the course is not a design course. Furthermore the project is given out near the midpoint of the semester. All of these factors contribute to the apparent difficulty of the project for this particular student population. Should the same project be given, for example, to senior engineering students in an upper level digital design course the project's difficulty would likely need to be significantly increased.

Another factor that increases the difficulty of the project is that it is given to the students at the beginning of a lab without prior knowledge of what the project will be. As discussed below, this is done partially to increase student communication challenges. But it also makes the project more difficult. If students were given the project in advance they would have more time to consider how to complete the overall design. The difficulty of the project is also affected by not assigning lab partners to the same group. This decision is made mainly to increase communication issues and simulate real world situations, but it also has an affect on the project's difficulty. But perhaps the most difficult part of the project is the criterion of implementing a half adder as opposed to a full adder. While the difference between a half and full adder has been discussed in class many students attempt to build a 4-bit half adder using four 1-bit half adders.

On the other hand there are also a number of factors that make the project easier for the students. Foremost among these is class coverage of the design of both a full adder and a half adder. Overflow is also covered. Notes from these lectures are available online as well.

Class coverage of multi-bit adders and of single-bit full and half adders is thorough. Students are presented with both unsigned and 2's complement addition. A standard SOP design of both a full and half adder is considered. Additionally, through the use of Karnaugh Maps a minimal design without exclusive-or gates (XORs) is considered. A further design using XORs is presented. Finally the text book contains a minimal 1-bit full adder design of only five gates. The main difficulty associated with each full adder is not how to build one, but which design to use.

Additionally, during the lab before the group project, students are required to build a half adder and simulate a full adder using the MultiSim [4, 5] electronic computer simulation package. This lab explicitly explains the difference between full and half adders. Most students are able to complete these circuits without much difficulty. Finally, as a bonus part of this lab, students are given the option of simulating a 2-bit full adder. Approximately 20% of the students normally choose to complete this bonus.

As a whole, at the beginning of the group project all students have previously built or simulated both a half and a full adder. Approximately 20% of students have simulated a 2-bit full adder. Class and lab discussion of the difference between a half and a full adder have also been provided. Nonetheless the majority of groups have a difficult time with the overall design of a multi-bit half adder, with especial difficulty understanding the difference between a half and full adder during the first lab period. On the other hand most groups are able to begin building the multi-bit full adder by the end of the second lab period.

It should be noted that the main purpose of the group project is for students to experience and learn from communication challenges. While the technical difficulties of the project could be greatly minimized or even eliminated this is not necessarily desirable. If all students, or even a majority, know how to complete the project with little difficulty then the communication requirements of the project are greatly minimized. Hence it is desirable for the project to be challenging for most students.

There are a number of variable factors that can be adjusted to make the project more or less difficult. For example the coverage of the design of a full adder is purposely made some time before the project is designed. Furthermore these notes mainly cover the design of a full adder but not a half adder. One simple way to tweak the difficulty of the project is by modifying either the depth or timing of the class coverage of this topic.

Another simple method to change the difficulty of the project is to modify the technical requirements. For example changing the project requirement from a half adder to a full adder would make is significantly easier. On the other hand changing the project to be an addition-subtraction unit makes the project significantly harder. Based upon past experiences with student groups this level of difficulty is not recommended for the students at EKU.

Another way to tweak the difficulty of the project is to change the number of lab periods for the project. While most groups have taken all three periods, with more prior help the group project could be reduced to two periods. On the other hand the number of lab periods could also be increased to lessen the difficulty of the project. Finally the project's difficulty can be tweaked by providing more assistance, both in class and in the lab, during the project itself. Ultimately, since individual groups vary even within the same class, this is an important way to help student groups.

Overall there is a complex interaction between student ability, the project's technical requirements and the amount of assistance given. These must be adjusted for each student audience in order to create a challenging but achievable project that maximizes communication requirements between low and high functioning students.

In addition to being adjustable to student ability the project is also scalable to varying number of students by simply changing the number of bits required in the arithmetic unit. Advantageously this can be accomplished without varying the design difficulty of the project. As shown in Table 1 the group size has ranged from 6 to 10 students while the number of bits of the arithmetic unit has varied from 4 to 6. For the student audience at our university, based upon the experiences gained with students who have attempted this project it is recommended that groups of up to 7 students be assigned a 4-bit half adder, with groups of 8 or 9 being assigned a 5-bit half adder and groups of 10 or more being assigned a 6-bit half adder. Note, however, that both the size and difficulty of the project must be adjusted based upon student ability and background.

Project Decisions Made With Minimal Communication Requirements

While the large group project is designed to require communication among group member there are also several parts of the project that need not involve all group members. As with any real world large project not all group members are likely to understand all parts of the complete design. Instead a few group members "in charge" need to understand the overall design while other group members may only need to complete a small portion of the project. For this project these decisions include whether or not to attempt simulation, how to design the overall adder, the design of the adder for the least significant bit, what design to use for each full adder, and the implementation of the overflow detection circuitry.

Results for each group for these decisions are shown in Table 2. For example the last group in the Table named Sp06TYBR778 was originally assigned a 5-bit half addition-subtraction unit with overflow. They were able to complete a 3-bit half adder without overflow. They attempted simulation but tried to have one individual build the entire adder. They used a full adder for the rightmost bit and used two half adders and other logic to implement each full adder. Finally they did not implement the overflow detection logic before completing the adder.

Table 2: Project One-Time Decisions

Group Name	Project Assigned	Portion Completed	Attempted Simulation	Implementation Method	Rightmost Bit Design	1-Bit Design	Pre-Made OverFlow
Sp05ALDU795	4 Bit HA O/F	All	N	Combination	FA	Book Min	Y
Sp05STGO865	4 Bit HA O/F	2 Bit HA	N	Combination	HA	XOR Min	N
Sp05KMAC880	4 Bit HA O/F	4 Bit HA No O/F	N	Combination	FA	Book Min	N
F05CHWI695	4 Bit HA O/F	All	Y	Combination	HA	XOR Min	N
F05TRFR685	4 Bit HA O/F	4 Bit HA No O/F	N	Combination	FA	Book Min	N
Sp06ANCU1075	6 Bit HAS O/F	2 Bit HA No O/F	Y	Combination	FA	Vary	N
Sp06TYBR778	5 Bit HAS O/F	3 Bit HA No O/F	Y	Individual	FA	2 HA	N

A typical example of a decision not requiring input from all group members is the implementation of the overflow detection circuitry. Since the project is for a 2's complement adder the students must compare the carry input of the sign bit to the carry output of the sign bit. When these two bits are not equal there is overflow. To experienced digital designers it is easy to realize that this requires a single exclusive-or gate. However this concept is not easily grasped by many students at the authors' university. More importantly, this part of the project need not be understood by all students. Normally the design of the overflow detection circuit is done by one or two high functioning students. This mimics many real world projects where not all parts are understood by all group members.

Another important issue that may not be understood by everyone is what multi-bit half addition includes. In many groups this involves a sometimes heated discussion among higher and moderate functioning students on whether this includes only half adders or whether full adders must be used as well. In yet other groups one or two students have looked this information up in references such as the internet. In yet another group a single student was able to successfully understand the overall design during the first lab period. This was the only group to finish in two laboratory periods. In yet other groups a single student researched the overall design between the first and second laboratory periods.

No matter what method was used to arrive at an overall design the most important thing to note is that not all students need to figure out or even understand the overall design. This can be done by only the highest functioning student, a subset of the entire group or even by a single student who comes to the instructor for help. Understanding what a multi-bit half adder is goes hand in hand with the overall design of the addition unit. The design of the addition unit is normally accomplished by the same students who understand what multi-bit half addition includes.

Another less critical decision that must be made only once is whether or not to use a full or half one-bit adder for the least significant bit. As shown in Table 2 five of seven groups have used a full adder for the least significant bit. While the discussion of whether a half adder or full adder for the least significant bit is often an interesting one it is less crucial than other decisions that must be made since either choice has advantages. Using a full adder means that the addition units for all bits are the same while a half adder results in less gates.

A decision that can be made by only a few group members but that is often made by all group members is whether or not to attempt to simulate the arithmetic unit. Since this decision is relatively non-technical most students participate in this decision. On the other hand in some groups students effectively make this decision by not discussing this option at all. Note that in the original project requirements given to the first five groups simulation was not mention. On the other hand, in the group project criteria given to the last two groups simulation was mentioned but not required. Overall three of seven student groups have attempted to simulate the group project as shown in Table. 2.

Communication Challenges and Project Decisions Common to the Entire Group

While the project involves a number of decisions that can be made by a subset of the student group there are many decisions that normally must be made by the entire group. These decisions are the most important of the project since they impose important communication challenges between group members. There are also a number of other project criteria that are imposed on student groups in order to encourage further communication. In summary, decisions and criteria that impose communication challenges include:

(1) Students being divided into groups without their normal small group partners.
(2) The project being given to students at the beginning of lab without prior knowledge of what the project will be.
(3) Students being forced to choose the organization and structure of their group.
(4) A small part of the grade being based upon student's opinion of each other.
(5) The level of difficulty of the project being such that students must share technical knowledge.
(6) A common one bit adder design being necessary.
(7) A common chip layout being helpful.
(8) A common color coding of wires being helpful.

Table 3 shows the outcomes of a subset of these common group decisions for each group. For example, the fifth group "F05TRFR675" was asked to complete a 4-bit half adder with overflow. This group was able to complete the 4-bit half adder but failed to complete the overflow detection circuit. The group used the same 1-bit design for each 1-bit adder but did not use the same physical layout for each 1-bit adder. Finally the group did color code at least some wires.

Table 3: Project Decisions Requiring Communication

Group Name	Project Assigned	Portion Completed	Same 1-Bit Gate Design	Same Physical Chip Layout	Color Code Wires
Sp05ALDU795	4 Bit HA O/F	All	Y	Y	Y
Sp05STGO865	4 Bit HA O/F	2 Bit HA No O/F	Y	N	Y
Sp05KMAC880	4 Bit HA O/F	4 Bit HA No O/F	Y	Y	Y
F05CHWI695	4 Bit HA O/F	All	Y	Y	Y
F05TRFR685	4 Bit HA O/F	4 Bit HA No O/F	Y	N	Y
Sp06ANCU1075	6 Bit HAS O/F	2 Bit HA No O/F	N	N/A	N/A
Sp06TYBR778	5 Bit HAS O/F	3 Bit HA No O/F	Y	N	Y

One factor that increases the communication requirements of the project is that it is given to the students at the beginning of a lab without prior knowledge of what the project will be. This is done primarily to increase student communication challenges. If students were given the project in advance they would have time to consider how to complete the lab before meeting with their group. Because students have no prior knowledge of the assignment the entire first lab period involves students communicating about issues such as how to organize their group, what half addition includes and what design to use. In all lab groups but one the first lab period has been used for communication and not actual implementation of the project.

The communication requirements of the project are also affected by not assigning lab partners to the same group. This not only forces students of varying technical abilities to work together, it often forces students to work with those who they are not friends with or those who they do not even know. These conditions are similar to many real world business projects.

A third factor that affects the communication requirements is that there is no assigned group structure. Should one student be put in charge? Should the group be divided into simulation and implementation teams? Who should build each individual adder? Who should work on the overflow detection circuitry? In the past all of these decisions have been left up to the student group. However there are a number of alternate options that should be considered. For example, the instructor could choose one student to be the group leader. Likewise the instructor could order the students to select a group leader. Should one or two group members research the overall design of the project before the second laboratory? How should these students be selected? These are all important group decisions.

A fourth factor that helps ensure that all students fully participate and communicate in group decisions is that a small portion of the overall grade is based upon students evaluations of each other. Students are informed of this before the project begins and are made to rank their team members from most helpful to least helpful at the end of the project. In this manner students know that they are always being evaluated - if not by the instructor then by their fellow team members. This mimics most real world team project where your overall evaluation is not only based upon your supervisor, but is based upon your peers as well. It should be noted that a few students have strenuously objected to this policy. This suggests that the reasons for this policy should be further explained when assigning the project.

A fifth factor that helps to ensure communication among group members is the level of difficulty of the project. It is desired that a few of the students be able to complete the general design of the project. Other students will not be able to come up with such a design. Therefore the more technically able students will be forced to share their ideas and understanding with the rest of the group. In most student groups this has worked out well. However in group F05CHWI695 all group members but one knew how to complete the overall design. Therefore this group faced less communication challenges than the other groups. Similarly group F05TRFR675 did not have any group members who were able to comprehend the overall design without significant assistance from the instructor. This also changed the communication dynamic for this group. On the other hand most groups have had a good mix of technically proficient students along with less advanced students. Overall, sharing technical knowledge is one of the major communication challenges of the project based upon choosing a suitable level of difficulty for the project.

Three other criteria that ensure communication challenges involve agreeing upon a common one-bit adder design. This includes a common gate level design, a common physical layout and common color coding of wires, at least for signals being passed between bits. Communication plays a crucial part in these decisions since the ‘correct’ way to accomplish these criteria is based solely on how the other members of the group are doing the same tasks. For example, the main criterion for color coding the wires in each full adder is that they match the other full adders. Whether green wires or blue wires are used for input bits is not important. What is important is that group members communicate with each other to standardize their color coding.

Similarly what is most important in choosing a design for each full adder is that they are the same. Through lecture, laboratory and the textbook, students are presented with both unsigned and 2's complement addition. A standard SOP design of both a full and half adder is considered first. Subsequently, through the use of Karnaugh Maps a minimal design without XORs is considered. A further design using XORs is presented. Finally the text book contains a minimal 1-bit full adder design of only 5 gates. These different designs are summarized below in Table 4. The main criterion associated with the gate level design each full adder is not how to build one, but that they all be the same. Finally it is also most helpful to have the physical layout of the chips be identical among all one-bit full adders.

Table 4: Potential 1-Bit Full Adder Designs

Design Name	Gates Required			Output Equations
	Multi-Input Gates with Uncomplemented Inputs Only	Multi-Input Gates and Complemented Inputs	Actual 2 Input Gates of Kit with Uncomplemented Inputs Only	
Standard SOP	12	9	20	S = AB'C' + A'BC' + A'B'C + ABC C = ABC' + AB'C + A'BC + ABC
Minimal SOP	12	9	18	S = AB'C' + A'BC' + A'B'C + ABC C = AB + AC + BC
XOR Minimal - SOP and XORs – No Combination	5	5	7	$S = A \oplus B \oplus C$ C = AB + AC + BC
Book Minimal - Combination Design	5	5	5	$S = A \oplus B \oplus C$ $C = (A \oplus B)C + AB$

Finally, Table 5 summarizes the overall decisions and completion percentages among the groups participating in the group project. This table shows, for example, that two of seven student groups fully completed the full adder including overflow while four of seven groups finished the full adder but not necessarily the overflow detection circuitry. Three of seven groups attempted simulation while six groups combined one-bit full adders to make their overall multi-bit adder. Five groups used a full adder for their least significant bit and four groups used a minimal design for each full adder. Only one group completed the overflow detection circuitry before attempting to have the instructor verify the project was completed. Six groups used a common gate level design; three groups had the same physical layout among eligible groups while every group chose to color code at least some wires.

Table 5: Project Decision Making Numbers and Percentages

	Completion Status		One Time Decisions					Group Decisions		
	Finished Full Adder with O/F	Finished Full Adder	Sim Attempt	Combined 1-Bit FA's	LSB Bit FA	Min 1-Bit Design	Pre-Made O/F	Common 1-Bit Design	Physical Layout	Color Code Wires
No. of Total	2/7	4/7	3/7	6/7	5/7	4/7	1/7	6/7	3/6	6/6
Percent	28.6%	57.2%	42.9%	85.7%	71.4 %	57.2%	14.3%	85.7%	50.0%	100%

Student Evaluations and Future Direction

As part of the group project students were asked to give their opinions on a number of questions about the group project. Anonymous evaluations were completed by 15 students filling out surveys at the end of the spring 2006 semester. During this semester the difficulty of the project was considerably increased by requiring both addition and subtraction and by increasing the number of bits. Table 6 shows each of the questions asked along with the average score for each question. Most questions involved five choices [Strongly-Disagree, Disagree, Neutral, Agree, Strongly-Agree] with "Strongly-Disagree" being the lowest in all cases and "Strongly-Agree" being the highest. If a one is associated with "Strongly-Disagree and a five with "Strongly-Agree" these responses may be converted to a numerical scale. This has been done and the results summarized. These results show that on questions about specific topics students rated the usefulness of the project as near 3.9 out of 5. The highest scores (4.1) were given for questions involving communication difficulties and sharing of technical knowledge while the lowest (3.7) was for decisions not made by all team members and teamwork.

Table 6: Student Survey Questions and Average Responses

Question	Average Response
The group project helped stress the importance of teamwork	3.7 of 5
The group project helped me appreciate communication difficulties in large groups	4.1 of 5
The group project helped me appreciate common implementation details, such as having a common design and common wire colorings	3.9. of 5
The group project helped me appreciate that not all members of a team need to understand all technical implementation details, such as the overflow implementation	3.7 of 5
The group project helped me appreciate that technical knowledge must be shared between team members to successfully complete a large project	4.1 of 5
The group project was more beneficial than an average other lab	2.5 of 5
Group Project Rating:	6.0 of 10
Quality of the Lab Instruction	8.3 of 10
Quality of the Labs Themselves	8.3 of 10

The average of 3.9 out of 5 is thought to be fairly high. On the other hand it must be kept in mind that average student responses on surveys are often very high. For example on faculty course evaluations the average on a four point scale is above three [6] while students also rate the difficulty of many classes as above average [7]. On the other hand, when asked to compare the group project to the other labs the average response was only 2.5 out of 5. This suggests that students may not have found this project, as a whole, as useful as the specific communication and teamwork lessons covered in the project.

In order to better 'normalize' the above data students were asked additional questions about other facets of the class and lab. These scores were then compared to the responses about the group project. The group project was rated on a scale from 1 (lowest) to 10 (highest). The overall rating of the group project was 6.0 out of 10. The average student rating when asked about the "Quality of Lab Instruction" was 8.3 out of 10 as was the average rating when asked about the "Quality of the Labs Themselves". These numbers are higher than the rating of the group project. These numbers also suggest that students may not appreciate the benefits of the group project or that they may be learning less from it than is hoped for.

On the other hand, it should be kept in mind that this survey was only completed during the spring 2006 semester. In this semester students were assigned the more technically difficult addition-subtraction criterion including a larger number of bits. This criterion proved much more difficult for students than the addition only criterion and is not recommended for this student audience. A small amount of data was collected when the less technically difficult addition only criterion was assigned. Students were asked to choose from a list of topics covered in the class and select two "learned lots", two "waste of time" and two "enjoyed most." For the semester with the less technically difficult project students selected "enjoyed most" twice, with no other selections of the group project being made. On the other hand for the semester with the more technically difficult project students selected "learned lots" once and "waste of time" five times. This data suggests that the addition-subtraction criterion is not rated as well as the addition only criterion and that the addition-subtraction criterion is too difficult for this student audience. Further data will be collected in the future for the group project with the addition only criterion

In the future ways to measure the benefits of the project should also be considered. This is challenging since the lessons taught in the project are not easily quantifiable. The experiences gained in the project may be very useful in certain other situations. Or they may not ever be used by some students. This is similar to many managerial lessons. For example the best way to deal with employee disciplinary problems is difficult to quantify and may vary from employee to employee. None the less this can be an important real world skill.

Many of the key communication issues covered in this paper have been discussed in class after the project has been completed. In the future, in order to improve the usefulness of the project and to stress the communication challenges involved (as opposed to the technical challenges), it recommended that the communication issues involved in large groups be briefly covered before the lab in addition to after it. It is felt that this will assist students in appreciating the communication and teamwork challenges they are about to face, as well as give them a better understanding of the objectives of the project.

Numerical methods to measure the projects effectiveness will also be refined. This will include further student surveys of their opinions of the lab. It is hoped that by assigning a project with a better level of technical difficulty student ratings will increase. Additionally, knowledge based multiple choice questions about group projects will be developed. These questions will be administered both before and after the group project. Results will then be compared to quantify the amount learned by the students.

Conclusion

Recently employed students often are put into large teams where effective communication and teamwork skills are essential. Academic assignments that challenge these skills in a truly large group setting are rare; however potential employers are looking for employees with such skills. Students at Eastern Kentucky University experience some of these communication challenges in a large group project associated with the introductory level digital electronics course for freshman-level students. The project simulates real world teamwork and communication difficulties. The proposed project requires a group of five or more students to build a large circuit that would not be possible for a smaller group. The project is scalable to varying group size and can be adjusted for different student audiences by varying the difficulty through depth of class coverage, or by requiring differing technical details. Group decisions that must be agreed upon by all group members, as well as decisions that can be made by a subset of the group, are analyzed. Results are presented that indicate student's ratings of the project and the percentage of students who make key group decisions as well as the outcome of each group's project.

References

[1] World-Wide Web URL http://www.eku.edu/. Last Accessed June 1, 2006.

[2] World-Wide Web URL http://www.eku.edu/futurestudents/requirements.php. Last Accessed June 1, 2006.

[3] World-Wide Web URL http://www.kme.eku.edu/newsletter4/csc_chair.html. Last Accessed June 1, 2006.

[4] World-Wide Web URL http://www.electronicsworkbench.com/. Last Accessed June 1, 2006.

[5] World-Wide Web URL http://www.electronicsworkbench.com/support/prosup5.html. Last Accessed June 1, 2006.

[6] Cashin, W.E. Student Ratings of Teaching: The Research Revisited. IDEA Paper No. 32. Manhattan, KS: Center for Faculty Evaluation and Development in Higher Education. 1995.

[7] Feldman, K.A. 1989. Instructional Effectiveness of College Teachers as Judged by Teachers Themselves, Current and Former Students, Colleagues, Administrators and External (Neutral) Observers. Vol. 30, Research in Higher Education,1989, pp. 37-194.

Biographies

VIGYAN "VIGS" CHANDRA has been employed as an associate professor at in the Department of Technology at Eastern Kentucky University since the fall of 2002. He holds graduate degrees in electrical engineering and manufacturing systems engineering from the University of Kentucky; along with certifications in several computer related areas. Having worked for several years as a maintenance engineer in a highly automated manufacturing facility, he has a broad background in electrical systems and computers. At EKU he teaches courses related to computer applications; communication, digital, analog, and machine control electronics. What he enjoys most about teaching computer electronics technology classes is working with students one-on-one. Along with the other faculty members in the department he has a keen interest in creating a student centered environment. His research is in the area of discrete event system control, and he is working along with Dr Ratnesh Kumar on developing some of the math behind the magic of automation.

MICHAEL J. SHELIGA joined Eastern Kentucky University's Department of Technology in the spring of 2004 as a part time faculty member and has been full time since fall 2004. He graduated with a Bachelor of Science in Electrical Engineering from Carnegie-Mellon in 1989 and from Notre Dame with his Master's in 1992. He went on to earn his doctorate in computer engineering in 1997 doing his thesis in parallel computers. He previously taught as an instructor at the University of Kentucky, as well as part time in the Kentucky Community and Technical College System, and wrote game-analysis and ticketing software for NFL teams. His research interests include multi-dimensional systems, hardware-software co-design and computer algorithms. His outside interests include cycling, Appalachian coal mining history, railroads and chess.