

A Model for Integrating Design Software into a Highway Design Course

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Abstract

The use of design software in highway surveying and design is becoming popular in industry. Graduates with the ability to employ design software are sought after commodities. They are likely to have an employment advantage with consultants or State Departments of Transportation.

The design software “Land Development Desktop (LDD)” has been integrated into the Highway Design course at the University of Pittsburgh at Johnstown (UPJ). The use of the software allows for open-ended design requirements that enable each team to search for feasible solutions that meet design guidelines of the American Association of State Highways and Transportation Officials (AASHTO) or the Pennsylvania Department of Transportation (PennDOT). Different teams may end up with different design solutions. The students understand through a semester-long project that they are the designers and not the software. They also learn that using the software is a process, which is likely to help them when using other highway design software. Senior students who have used the software in their senior design projects have produced high quality design reports and drawings.

This paper describes the process of integrating the LDD software in the Highway Surveying and Design course. The course objectives and the design project components are presented and discussed. The experience gained from redesigning the course to include computer applications at various stages of a semester-long design project provides useful guidance to those considering ways to integrate design software into existing courses.

Introduction

Accreditation Board for Engineering and Technology (ABET) outlines Civil Engineering Technology Program Criteria for accreditation.⁽¹⁾ One of the requirements of the new criteria is that programs must demonstrate that graduates are capable of planning and preparing design and construction documents including engineering drawings. Other requirements call for graduates to be capable of applying basic technical concepts to the solutions of civil problems as well as performing standard analysis and design in at least three areas that may include transportation. Integrating the LDD software into the highway course is a step to help achieve the above mentioned ABET accreditation criteria as further discussed in the section on evaluation.

Highway Surveying and Design in Civil Engineering Technology (CET) at the University of Pittsburgh at Johnstown is a required course at the junior level. Only Civil Engineering Technology (CET) students take the Highway Design course and it is preceded by two-sophomore level courses in surveying.

The Highway course is design and problem solving in nature. It develops students' ability to use mathematical formulas, specifications and guidelines by design agencies, assumptions and finally common sense to recommend solutions for a given highway problem. The Highway Design class contained twenty nine (29) students.

The design software "Land Development Desktop (LDD)" has been introduced to students to aid in the analysis and design of a highway facility. LDD is an AutoCAD based software, which is available among a number of other computer programs on the UPJ computer network. The software covers topics that include roadway design, hydrology, site grading, and surveying. Initially, the software was introduced as a demonstration class to illustrate the designing ability of the software, especially performing design calculations and producing project drawings. By the end of the semester, students expressed appreciation for the software and demanded more integration of the software in the design process.

Implementation

The plan to integrate the LDD software into the course was presented to students on the first day of classes. The idea was discussed along with the course syllabus. The intention of using the software as a learning tool and as a way to aid in both analysis and design was also discussed. A copy of the course syllabus is given in Appendix A. The syllabus outlines the course objectives, expectations, grading system, detailed lecture and lab schedules, and reading assignments.

Cooperative learning was used as the instruction style in the lab. Cooperative learning is defined as instruction that involves working in teams to accomplish an assigned task and produce a final product, under conditions that include the elements: *Positive Interdependence, Individual Accountability, Face-to-Face Promotive Interaction, Appropriate Use of Teamwork Skills, and Regular Self-assessment of Team Functioning*.⁽²⁾ An extensive body of educational research confirmed the effectiveness of cooperative learning in higher education.⁽³⁾

The term "Team" is used here and not "Group" because in teamwork, activities span for a long time (weeks, whole semester) while activities span short time frame for group work. Also, teams are formed carefully while groups are formed spontaneously.⁽⁴⁾ The students work in teams of three or four and are carefully formed by the instructor. Academic research indicates that instructor formed teams perform better than totally self selected teams.⁽⁵⁾

At the beginning of the semester, students are asked to fill out a student data sheet in which they provide information about their technical background and experiences inside and outside of school as well as their interests. The student data sheet provides feedback on each student's prior learning to help determine the "starting" point of instruction.⁽⁶⁾ The student data sheet also includes information that will help the instructor in team formation. A student data sheet is included in Appendix B.

One provision of team formation was for each student to identify a student with whom he/she would like to work and one student with whom he/she would prefer not to be teamed.⁽⁷⁾ Students are told that their choices will be taken into consideration but are not guaranteed because of

feasibility problems such as the case when many students name one student whom they wish to work with. Another consideration was that students with a background or experience in LDD or similar software are distributed over the groups such that the few students who have a good background in LDD from summer internships or part time jobs do not end up in the same team.

The LDD design software is integrated into the course through a semester long project assigned to the students at the beginning of the semester. The project is broken into tasks that can be completed in one or two weeks. The requirements of each design assignment is outlined and given to students as a handout. Sample handouts are given in Appendix C. The students first carry out the design tasks manually to fully understand the design process then they employ the LDD software to verify their manual design. The students then use the advanced features of the software to carry out sensitivity analysis and produce different design alternatives in a relatively short time. The general sequence by which the software is integrated into the course is shown in the lab schedule as shown in the course syllabus given in Appendix A.

When the meeting with students is scheduled for computer applications using the LDD, students meet in the computer lab. The capacity of the lab is limited to 15 to allow for full interaction between students and instructors to ensure that students follow the instructions correctly. The use of the software is presented to students through an active session using a real design example. The presentation follows a carefully planned outline, with built-in questions and side notes to stimulate class discussions as well as to motivate students' interests. Each student is required to get access to the software and to work out a design example in a step-by-step approach along with the instructor. Students also take notes on the discussions of advanced features that may not be included in the example but could be part of their highway design project. The students get a tutorial hand out to help them perform the different tasks. They are also required to complete a reading assignment from the lab textbook, which provides a basic understanding of the tools found in Land Development Desktop and its two add-ins (Surveying and Civil Design). ⁽⁸⁾

The design requirements are mixed between being general (open-ended) and specific in order to allow members of each team to search for feasible solutions that meet AASHTO or PennDOT design guidelines. As a result, different teams may end up with different design solutions. Students are challenged to think and search for answers but are yet given sources of information that will help them find such answers. Students are encouraged to think about the logic behind their choices. Any suggestion should be supported by documented design guidelines or specifications and it should make sense too. Grading student performance and teamwork is done such that individual accountability is considered in the grading. With each submission, students are asked to fill a sheet to report on the rating of each team member with respect to the degree to which each member has fulfilled his/her responsibilities in completing the lab assignment. ⁽⁵⁾ The Autorating System is used to assign a final grade to each team member. ⁽⁹⁾

Evaluation

A questionnaire was administered at the end of the semester to obtain feedback from students on the idea of integration of the Land Development Desktop (LDD) design Software in the Highway Surveying and Design Course. A copy of the actual form can be found in Appendix D.

The questionnaire consists of 12 questions. In nine questions (1 -8, and 10), the answer format is multiple-choice such that the range of responses is from "1" meaning "Definitely No" to "5" meaning "Definitely Yes". The highway class consists primarily of juniors with few seniors.

Table 1 presents the student responses with respect to their understanding of the software abilities and the usefulness of utilizing the software in the design process. The percent of maximum score and average student response have been used to quantify the response by students to these questions as shown Table 1. The maximum score is the number when all students select "Definitely Yes" which has a value of five (5) as their response in favor of the idea (i.e. maximum score = 150 for a class of 30 students).

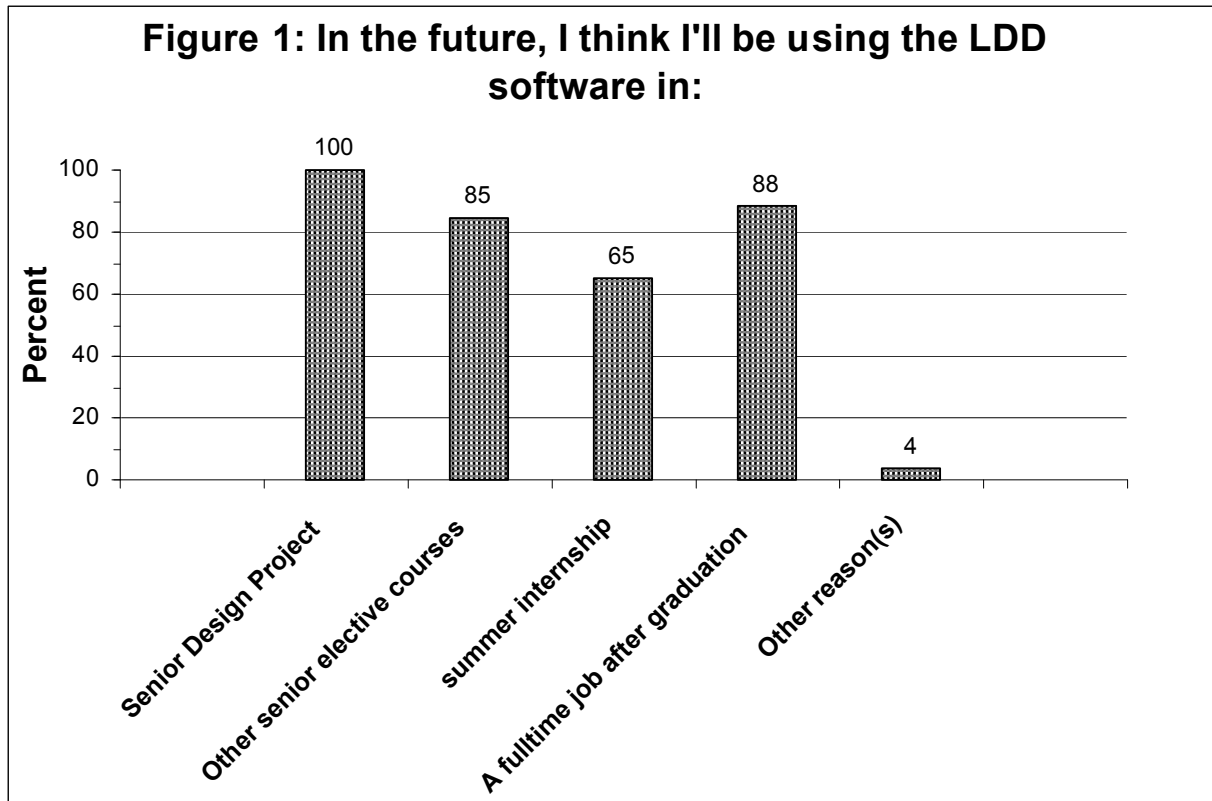
Table 1: Student Responses to questions on Integrating LDD in Highway Design

No.	Question	Response	
		% Of Maximum Score (Max=100)	Average (5 fro strongly agree)
Q1	Using the LDD software enabled me to verify the manual calculations or design	89.2	4.5
Q2	The LDD software helped me understand the design process better	76.9	3.8
Q3	The LDD software allows for producing different design alternatives in relatively short time	92.3	4.6
Q4	The LDD software has the ability to design according to AASHTO design criteria	92.3	4.6
Q5	The LDD software produces professional drawings with settings controlled by the designer	93.1	4.7
Q6	My background in AutoCAD made it relatively easy for me to use the LDD software	74.6	3.7
Q7	When using the LDD software, I understand that I am the designer and not the software	89.2	4.5
Q8	Learning the design process using the LDD software is likely to be helpful when using other design software	81.5	4.1
Q10	Learning the design process using the LDD software is likely to give me an employment advantage if I decided to work in the field of transportation.	95.4	4.8

The following comments can be made on Table 1:

- The majority of students (score 4.5) indicated that using the LDD software enabled them to verify the manual calculations or design. The verification process was one of the requirements of their submissions. The verification process requires that students understand all parameters used in the design along with knowledge of software default values.
- Students understood the design process through manual work first before utilizing the LDD software. That explains the relatively lower score (3.8) of the second question on the ability of the LDD software to help students understand the design process better.
- Almost all students have a good feel of the abilities of the software in analysis and design (Q3 to Q5) including the software ability to produce different design alternatives in a relatively short time, the LDD ability to design according to AASHTO design criteria and to produce professional drawings.
- With a score of 3.7, students indicated their background in AutoCAD made it relatively easy to use the LDD software. Students take AutoCAD in their freshman year; that experience helps them in developing proficiency with the LDD software, which is AutoCAD based. The relatively low score is an indication that the LDD has many new commands especially in the design process. Students will have to practice no matter how good they are in AutoCAD.
- Most students agree that they are the designers and that the software is only a tool to aid in the design process. Students also understand that the feasibility and quality of their designs reflect the ability and experience of the designer and not necessarily the software. A neat computer output does not necessarily mean a good design. In other words, the designer takes either the credit or the blame for the quality of design.
- Many students from their summer internship or part-time employment realized that the design process using the LDD software is not very different from other software. Therefore, the experience they gained from using this software is likely to be helpful when using other design software.
- Finally, the vast majority of students feel that learning the design process using the LDD software is likely to give them an employment advantage if they decided to work in the field of transportation. Private consultants and government agencies all use software in the analysis and design of highway facilities and are likely to prefer graduating engineers with some experience in using design software.

Question 9 in the questionnaire gave students options regarding where they may use the LDD software beyond this course. The responses are displayed in Figure 1.



As shown in Figure 1, students clearly indicated that using LDD is likely to go beyond this course. Using LDD in senior design came as their first choice simply from attending senior design project presentations. The majority of students (>90%) indicated that they are aware of the fact that the LDD software is widely used by design firms throughout the region.

Finally, all students in this class unanimously found integrating the Land Development Desktop (LDD) in the highway surveying and design course to be a useful computer application that should be continued.

Some students also made written comments (see Appendix E). They were in general supportive of using the LDD software in design. Some students indicated they wish to see more utilization of the LDD software in the design process. Other students liked using the software to the extent that they wished if it would replace the time consuming traditional manual work.

Summary

- A design software “Land Development Desktop (LDD)” has been integrated into the Highway Design course at the University of Pittsburgh at Johnstown (UPJ). The use of the software allowed for open-ended design requirements that enable students to search for feasible solutions that meet design guidelines of the American Association of State Highways and Transportation Officials (AASHTO) or the Pennsylvania Department of Transportation (PennDOT).
- Integrating the LDD software into the highway course supports the college strategic goals and objectives and help in meeting ABET accreditation requirements.
- The software was introduced to students through a semester long project and in a cooperative learning environment that involves having students working in teams to accomplish the assigned tasks.
- All students in this class expressed appreciation for integrating the Land Development Desktop (LDD) in the highway surveying and design course as a useful computer application that should be continued.

References

1. Accreditation Board for Engineering and Technology (ABET), “Criteria for Accrediting Engineering Technology Programs: Effective for Evaluations During the 2002-2003 Accreditation Cycle,” Baltimore, MD. , November 2001.
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3. Felder, R., Brent, R., “How to Improve Teaching Quality,” Quality Management Journal, Vol. 6, No. 2, 1999.
4. Bucknell’s Catalyst Team on Teamwork, “Practical Guide to Teamwork,” College of Engineering, Bucknell University, 2002.
5. Felder, R., Brent, R., “Effective Teaching: A workshop,” Given at Bucknell University, Lewisburg, PA, May 2001.
6. The American Society of Civil Engineers (ASCE), “ExCEEEd Teaching Workshop,” Northern Arizona University, August 2002.
7. Bucknell’s Catalyst, “Engineering Engineering Education: A Catalyst for Change,” A workshop given at Bucknell University, June 2002.
8. Zimmerman, P., “Effective Harnessing AutoCAD Land Development Desktop,” autodesk press, 2001.
9. Brown, R., “Autorating: Getting individual marks from team marks and enhancing teamwork,” 1995 Frontiers in Education Conference Proceedings.

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Appendix A: Course Syllabus

UNIVERSITY OF PITTSBURGH AT JOHNSTOWN CIVIL ENGINEERING TECHNOLOGY

Course Outline

COURSE:	CET 1121 - Highway Surveying and Design
CREDIT:	Three (3) Credit Hours
TERM:	Fifth or Seventh
TEXT:	“Traffic and Highway Engineering”, by Garber and Hoel, Third Edition, 2002.
REFERENCES:	<ol style="list-style-type: none">1. “A Policy on Geometric Design of Highways and Streets” by the American Association of State Highway and Transportation Officials (AASHTO), 1990 Edition.2. “Design Manual Part 2, Highway Design”, Publication No. 13M, Pennsylvania Department of Transportation (PennDOT), 2000.3. “Guidelines for The Design of Local Roads and Streets”, Publication No. 70M, Pennsylvania Department of Transportation (PennDOT), 2000.4. “Harnessing AutoCAD Land Development Desktop”, by Phillip J. Zimmerman , autodesk press, 2001.
PREREQUISITES:	CET 0020 and CET 0021
OBJECTIVE:	To develop fundamental skills in performing highway location surveys and design. Emphasis is placed upon horizontal and vertical alignments, cross-sections, earthwork quantities, construction stakeouts, and preparation of design plans. Computer Land Development Desktop (LDD) will be utilized in planning and design of a highway.
TIME DISTRIBUTION:	Two hours of lecture and three hours of lab per week.
STUDENT PREPARATION:	Reading assignments, homework problems, and lab work.
GRADING:	Two term exams, a final exam, homework, and design projects.

Dr. Maher M. Murad
August 2002

Lecture Schedule:

<u>Week No.</u>	<u>Topic</u>	<u>Reading</u>	<u>Pages</u>
1	Introduction to Transportation Systems and Organizations	Chap 1&2	3-14, 26-36
2	Characteristics of the Driver, the Pedestrian, the Vehicle, and the Road	Chap 3	43-79
3	Principles of Highway Location	Chap 15	652-659
4	Highway Functional Classification and Design Standards	Chap 16	672-688
5&6	Design of Horizontal Alignment	Chap 16	705-723
7&8	Design of Vertical Alignment	Chap 16	689-705
9&10	Highway Cross-Sections and Volume of Earthwork	Chap 15	659-667
11&12	Intersection Design	Chap 5	215-265
13&14	Design Plan Preparation	Chap 15	667-668

Laboratory Schedule:

<u>Week No.</u>	<u>Topic</u>
1	Introduction and Site Visit
2-3	Staking out Preliminary Route
4	Alignment Adjustments
5	Design of Circular Curves
6	Setting out Circular Curves
7	Horizontal Alignment with LDD
8	Centerline Profile and Cross-Sections
9	Design of Vertical Alignment
10	Vertical Alignment with LDD
11	Earthwork Calculations
12	Cross-Sections and Earthwork Computations with LDD
13	Design Plan Preparation
14	Final Report Submission

Exam Schedule:	Exam 1	October 2, 2002
	Exam 2	November 6, 2002
	Final Exam	December 9, 2002

Grading:	Exam 1	15%
	Exam 2	15%
	Final Exam	20%
	Homework	10%
	Project Reports	40%

Appendix B: Student Data Sheet

**UNIVERSITY OF PITTSBURGH AT JOHNSTOWN
CIVIL ENGINEERING TECHNOLOGY**

CET 1121 - Highway Surveying and Design

Student Data Sheet

Name: _____

Hometown/State: _____

Projected Year of Graduation: _____

E-mail Address: _____

Class/Work Schedule:

Period	Monday	Tuesday	Wednesday	Thursday	Friday
8:00-8:50					
9:00-9:50					
10:00-10:50					
11:00-11:50					
12:00-12:50					
1:00-1:50					
2:00-2:50					
3:00-3:50					
4:00-4:50					
Evening					

Work Experience (employer, location and responsibilities):

Surveying Experience (type of surveying, equipment and software used...etc):

When did you take the surveying courses CET 0020 and CET 0021?

Name a student in your class that you like to work with in the lab (if any):

Name a student in your class that you do not like to work with in the lab (if any):

Extra Curricular Activities: _____

Other information that you wish to share with me:

The two most important things that you want to learn in this course:

Questions that you may have:

Appendix C: Sample of a Lab Assignment

UNIVERSITY OF PITTSBURGH AT JOHNSTOWN ENGINEERING TECHNOLOGY

CET 1121 – Highway Surveying and Design

Highway Design Project – Setting Out a Simple Horizontal Curve

The most common method of locating a simple curve in the field is by deflection angles. Typically, the instrument is set up at the point of curve (PC) and the deflection angles are tuned from the tangent line joining consecutive whole stations.

I. Office Work:

- Prepare and complete curve computations for one circular horizontal curve.
- Curve computations should include at least the following:
 - 1) Curve number, radius, and length
 - 2) Location of the point of intersection (PI)
 - 3) Tangent length (T)
 - 4) Deflection angles to whole stations from point of curve (PC). Round deflection angles to nearest half-minute.
 - 5) Length of chords joining whole stations.

II. Field Work:

- 1) Measure off the tangent distance (T) from the PI to locate the PC and PT on the appropriate tangent lines.
- 2) Set up the instrument at the PC.
- 3) Sight on the PI and set the horizontal angle to zero.
- 4) Turn off an angle $= \frac{\Delta}{2}$ in the direction of PT. If the computations for T and the field measurements have been performed correctly, the line of sight at the $\frac{\Delta}{2}$ angle will fall over the PT mark (± 0.10 ft). If this does not

occur, the T computations and then the field measurements should be repeated.

- 5) Set the curve stakes by turning off the deflection angle and measuring the chord distance for the appropriate station.
- 6) The instrument should be left at PC, if possible, for the entire curve stake out, whereas the distance measuring moves continually forward from station to station. The rear tapeman keeps his/her body to the outside of the curve to avoid blocking the line of sight from the instrument.
- 7) After the last whole station has been set, measure the chord distance from that station to PT and compare to the computed value.
- 8) After the curve has been deflected, walk along the curve looking for abnormalities.
- 9) If the entire curve cannot be deflected in from PC because of loss of line of sight due to intervening obstacles, move up on the curve as follows:
 - i. Move the instrument to the last station that was established from PC.
 - ii. Set the horizontal angle to zero and backsight on PC with the telescope inverted (plunged).
 - iii. Reinvert the telescope so that it is oriented to the curve.
 - iv. Set the appropriate deflection angle (as calculated) for the desired station location.
 - v. Continue setting out the remaining stations from this location.
 - vi. The move up on the curve can be repeated as often as is necessary to complete the curve layout.

III. Report:

- A) Organize and submit a report that contains the following:
 - 1) Curve design computations (**manually**).
 - 2) Curve design computations using the **LDD** software.
 - 3) Field setting out of a horizontal curve.
- B) The report format should be similar to that of the previous report.

Appendix D: Integrating Design Software in Highway Surveying and Design.

Questionnaire

Please answer each of the questions below based on your individual experience with the use of Land Development Desktop (LDD) in the highway surveying and design course.

Course Name: _____ Academic Level: _____ Fr _____ So. _____ Jr. _____ Sr.

Please circle the appropriate response to each of the questions below. The range of responses is from "1" meaning "Definitely No" to "5" meaning "Definitely Yes".

- | | | | | | |
|---|---|---|---|---|-------|
| 1. Using the LDD software enabled me to verify the manual calculations or design. | 1 | 2 | 3 | 4 | 5 |
| 2. The LDD software helped me understand the design process better. | 1 | 2 | 3 | 4 | 5 |
| 3. The LDD software allows for producing different design alternatives in relatively short time. | 1 | 2 | 3 | 4 | 5 |
| 4. The LDD software has the ability to design according to AASHTO design criteria. | 1 | 2 | 3 | 4 | 5 |
| 5. The LDD software produces professional drawings with settings controlled by the designer. | 2 | 3 | 4 | 5 | |
| 6. My background in AutoCAD made it relatively easy for me to use the LDD software. | 1 | 2 | 3 | 4 | 5 |
| 7. When using the LDD software, I understand that I am the designer and not the software. | 1 | 2 | 3 | 4 | 5 |
| 8. Learning the design process using the LDD software is likely to be helpful when using other design software. | 1 | 2 | 3 | 4 | 5 |
| 9. In the future, I think I'll be using the LDD software in: | | | | | |
| Ø Senior Design Project | | | | | _____ |
| Ø Other senior elective courses | | | | | _____ |
| Ø summer internship | | | | | _____ |
| Ø a fulltime job after graduation | | | | | _____ |
| Ø Other reason(s), specify | | | | | _____ |

10. Learning the design process using the LDD software is likely to give me an employment advantage if I decided to work in the field of transportation. 1 2 3 4 5

11. I am aware that companies in the region do utilize the LDD software in professional design:

YES

NO

12. Overall, I found integrating the Land Development Desktop (LDD) in the highway surveying and design course to be a useful computer application that should be continued.

YES

NO

Please feel free to make any additional comments:

Appendix E: Students' comments with respect to using the LDD software

"It is a powerful tool and we are not using it enough"

"Incorporate more earthwork design calculations in LDD"

"I believe Prof. Murad did a great job working with LDD and manual calculations. I also think that even more LDD could be helpful"

"Maybe make Fridays (a day normally not in class) a day to learn LDD!"

"The LDD is very important, but the basic hand methods are absolutely necessary"

"I think the whole Eng. Program should utilize LDD but not too many courses teach it"

"More emphasis on the use of LDD will give us a step ahead. The exposure was good but perhaps any additional use for LDD could be explored"

"We should make it mandatory for every thing we design by hand and should be verified using LDD software. You can never know enough about CAD. It is so helpful"