SF2812 APPLIED LINEAR OPTIMIZATION Spring 2015
Course analysis

- **Course number, course name, credits, student group, period of study**
  SF2812 Applied linear optimization, 7.5hp, advanced level, elective for F, M, T, and master in mathematics, scientific computing and aerospace engineering, period 3.
- **Teachers**

Instructor and examiner:	Anders Forsgren
Exercise leader and project leader:	Axel Ringh

- **Course literature**
  - *Linear and Nonlinear Programming*, second edition, by I. Griva, S. G. Nash and A. Sofer, SIAM, 2009.
  - *Exercises in applied linear optimization, 2014/2015.*
  - Excerpt from chapters 1 and 4 in *Introduction to Stochastic Programming*, by J. R. Birge and F. Louveaux, Springer, 1997.
  - Excerpt from chapter 1 in *Integer and Combinatorial Optimization*, by G. L. Nemhauser and L. A. Wolsey, John Wiley & Sons, 1988.
  - Excerpt from the book *Applied Mathematical Programing*, by S. P. Bradley, A. C. Hax and T. L. Magnanti, Addison-Wesley, 1977.
  - Article *An applications oriented guide to Lagrangian relaxation*, by M. L. Fisher. From the journal *Interfaces*, vol. 15, pp. 10–21, 1985.
  - Article *The Lagrangian relaxation method for solving integer programming problems*, by M. L. Fisher. From the journal *Management Science*, vol. 27, pp. 1–18, 1981.
  - *Lecture notes in applied linear optimization, 2014/2015.*
  - *GAMS, A user's guide.*
  - *GAMS.* GAMS is installed in the Ubuntu computer rooms. It may also be downloaded from the web for use on a personal computer.
  - Two project assignments that are handed out during the course, February 3 and February 17 respectively.
- **Number of registered students (in Ladok):** 72 of which 5 are PhD students
- **Number of students passing the projects:** 72 of which 5 are PhD students
- **Number of students passing the first exam:** 62 out of 69

The questions below are related to the LEQ course evaluation

1. **Course design**
   Briefly describe the course design (learning activities, examinations) and any changes that have been implemented since the last course offering.

   The course is designed around two projects and lectures/exercise sessions. The projects are carried out in groups, and the students use a high-level optimization modeling language, GAMS. Modeling is examined throught the projects, theory and method knowledge is examined through the final exam. This is the same setup as last year.

2. **The students' workload**
   Does the students' workload correspond to the expected level (40 hours/1.5 credits)? If there is a significant deviation from the expected, what can be the reason?

   The expected workload would be 20 hours per week. The questionnaire shows a large spread. I think it differs depending on the students' background. Also, I think it is difficult for them to estimate how much time they spend on the projects.

3. **The students' results**
   How well have the students succeeded on the course? If there are significant differences compared with previous course offerings, what can be the reason?

   In the projects, the students did well. Compared to last year, I would say that the result on the first project was a bit weaker. I think that the feedback on the first project made them work harder on the second one, where the result was as good as last year. The result on the final exam was very good. I cannot see that the exam was particularly easy, but I guess the students felt that way.

4. **Overall impression of the learning environment**
   What is your overall impression of the learning environment in the polar diagrams? If there are significant differences between different groups of students, what can be the reason?

   The overall impression based on the polar diagrams is that this is a well functioning learning environment.

5. **Analysis of the learning environment**
   Can you identify some stronger or weaker aspects of the learning environment in the polar diagram - or in the response to each statement - respectively? Do they have an explanation?

   Stronger aspects concern stimulating tasks, collaboration, belonging, constructive alignment, feedback and security. Weaker aspects concern choices and exploration on one's own.

   I think the main strengths of the course are based on the projects, the students are well motivated and work hard. As for the weaknesses, I assign the groups and also assign the tasks to each group. This is a choice on my part. assigning groups is important. Letting the groups choose projects might be diffucult to handle.

6. **Answers to open questions**
   What emerges in the students' answers to the open questions? Is there any good advice to future course participants that you want to pass on?

   The students are in general quite happy with the course. In particular, they apprecaite the work with the projects. Axel gets very favorable comments. As instructor it is of course very nice to see that several students stress the importance of going to lectures and exercise sessions.

7. **Priority course development**
   What aspects of the course should primarily be developed? How could these aspects be developed in the short or long term?

   The course has a working setup and I do not plan any major changes right now. The course was designed for about 35 partipants. Now we have over 70, the number of

students almost doubled last year and this high number was maintained this year. The feedback sessions are quite time-consuming for such a relatively large number of students. However, it is worth keeping them.

Minor changes would be to announce in advance which exercises to be handled at the exercise session, and also to develop new projects.

8. Other information

Is there anything else you would like to add?

The results from the course evaluation are very much in line with my own view of the course.

LEQ Footprint

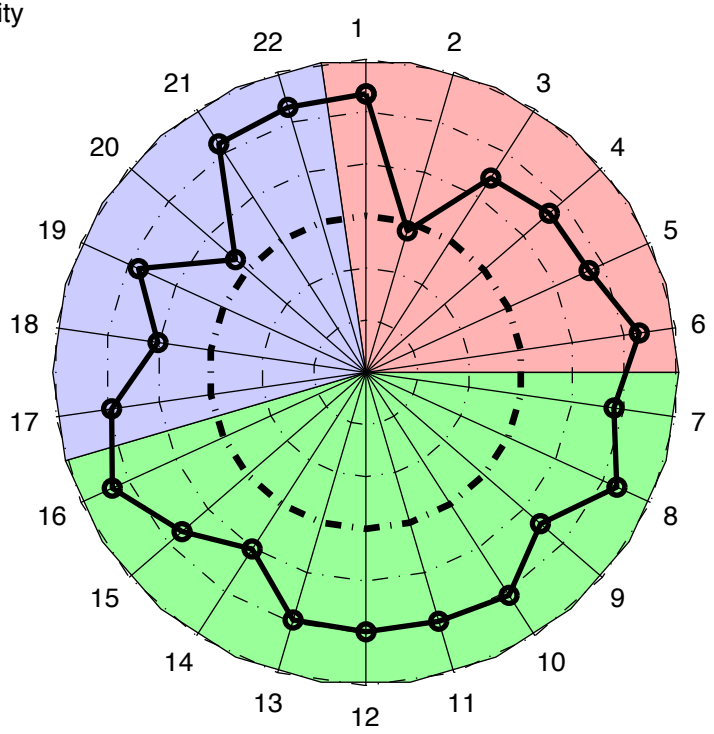
SF2812 Applied linear optimization

Number of respondents: 38

Red area: Meaningfullness

Green are: Comprehensibility

Blue area: Manageability



KTH Learning Experience Questionnaire (LEQ) v3.1.0

Established 2015-01-12

Estimated workload

0. On average, how many hours/week did you work with the course (including scheduled hours)? 1-3/4-6/… /37-39/≥40 hours/week (l)

Meaningfulness – emotional level

Stimulating tasks

1. I worked with interesting issues (a)

Exploration and own experience

2. Out of interest I explored parts of the topic on my own* (a)
3. I could learn by trying out my own ideas (b)

Challenge

4. The course was challenging in a stimulating way (c)

Belonging

5. I felt togetherness with other course participants* (d)
6. The atmosphere in the course was open and inclusive (d)

Comprehensibility – cognitive level

Clear goals and organization

7. The learning objectives helped me understand what I was expected to achieve (e)
8. I understood how the course was organized and what I was expected to do (e)

Understanding of subject matter

9. I understood what the teachers were talking about (f)
10. I was able to learn from concrete examples that I could relate to (g)
11. Understanding of key concepts was given high priority (h)

Constructive alignment

12. The course activities helped me to reach the learning objectives efficiently (i)
13. I understood what I was expected to learn in order to get a particular grade* (i)

Feedback and security

14. I regularly received feedback that helped me see my progress* (j)
15. I could practice and receive feedback without any grading being done (j)
16. The assessment on the course was fair and honest (k)

Manageability – instrumental level

Sufficient background knowledge

17. My background knowledge was sufficient to follow the course (f)

Time to reflect

18. I regularly spent time to reflect on what I learned (l)

Variation and choices

19. I was able to learn in a way that suited me (m)
20. I had opportunities to choose what I was going to do* (m)

Collaboration

21. I was able to learn by collaborating and discussing with others (n)

Support

22. I was able to get support if I needed it (c)

General questions

23. What was the best aspect of the course?
24. What would you suggest to improve?
25. What advice would you like to give to future course participants?
26. Is there anything else you would like to add?

The student's profile

27. I am: Female/Male/Other/Do not want to disclose
28. I am: International Master's student/International exchange student/
    Swedish student in year 1-3/Swedish student in year 4-5/
    Other type of student/Do not want to disclose

---

*Not included in a slightly shorter version with 17 statements.

The letters within parenthesis (a, b, …) refer to the learning factors that LEQ is intended to examine (enclosed).

In the electronic versions of the questionnaire, the statements are presented in the following order: {7, 1, 18, 2, 17, 5, 14, 4, 20, 9, 11, 15, 12, 21, 6, 19, 8, 10, 22, 16, 3, 13}.

Factors from the literature that LEQ intends to examine

We tend to learn most effectively (in ways that make a sustained, substantial, and positive influence on the way we think, act or feel) when:

a) We are trying to answer questions, solve problems or acquire skills that we find interesting, intriguing or important (stimulating tasks and exploration: 1, 2)*;
b) We can speculate, try out ideas (intellectually or practically) and learn from experience, even before we know much about the subject (own experience: 3);
c) We are able to do so in a challenging yet supportive environment (challenge and support: 4, 22);
d) We feel that we are part of a community and believe that other people have faith in our ability to learn (belonging: 5, 6);
e) We understand the meaning of the learning objectives, how the environment is organized and what is expected of us (clear goals and organization: 7, 8);
f) We have sufficient background knowledge to manage the present learning situation (sufficient background knowledge and understanding of subject matter: 17, 9);
g) We can learn inductively by moving from specific examples and experiences to general principles, rather than the other way around (und. of subject matter: 10);
h) We are challenged to develop a proper understanding of key concepts and successively create a coherent whole of the content (und. of subject matter: 11);
i) We believe that the work we are expected to do will help us to reach the learning objectives (constructive alignment: 12, 13);
j) We can try, fail, and receive feedback in advance of and separate from any summative judgment of our efforts (feedback and security: 14, 15);
k) We believe that our work will be considered fairly and honestly (security: 16);
l) We have sufficient time to learn and devote the time necessary to do so (own effort and time to reflect: 0, 18);
m) We believe that we are in control of our own learning, not manipulated (variation and choices: 19, 20);
n) We can work collaboratively with other learners struggling with the same problems (collaboration: 21);

---

*The information within parentheses refers to different aspects of the learning environment and the numbering of the corresponding statements in LEQ.

Literature

Bain, K. (2004). *What the Best College Teachers Do* (Chapter 5, pp. 98-134). Cambridge: Harvard University Press (see also http://www.bestteachersinstitute.org - accessed 2015-01-12).

Biggs J. & Tang, C. (2011). *Teaching for Quality Learning at University* (Chapter 6, pp. 95-110). Maidenhead: McGraw Hill.

Elmgren, M. & Henriksson, A-S. (2014). *Academic Teaching* (Chapter 3, pp. 57-72). Lund: Studentlitteratur.

Kember, K. & McNaught, C. (2007). *Enhancing University Teaching: Lessons from Research into Award-Winning Teachers* (Chapter 5, pp. 31-40). Abingdon: Routledge.

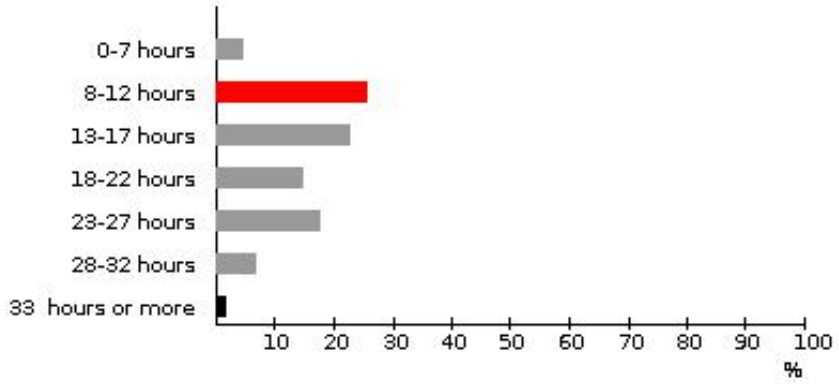
Ramsden, P. (2003). *Learning to Teach in Higher Education* (Chapter 6, pp. 84-105). New York: RoutledgeFalmer.

Survey results

Survey:	Course evaluation v3.1.0
Status:	open
Date:	2015-04-15 13:15:09
Group:	Participants (SF2812 Applied linear optimization)
Answered by:	38(82) (46%)

Estimated workload

On average, how many hours/week did you work with the course (including scheduled hours)?



answer choice	0-7 hours	8-12 hours	13-17 hours	18-22 hours	23-27 hours	28-32 hours	33 hours or more
distribution	5,3%	26,3%	23,7%	15,8%	18,4%	7,9%	2,6%
number	(2)	(10)	(9)	(6)	(7)	(3)	(1)

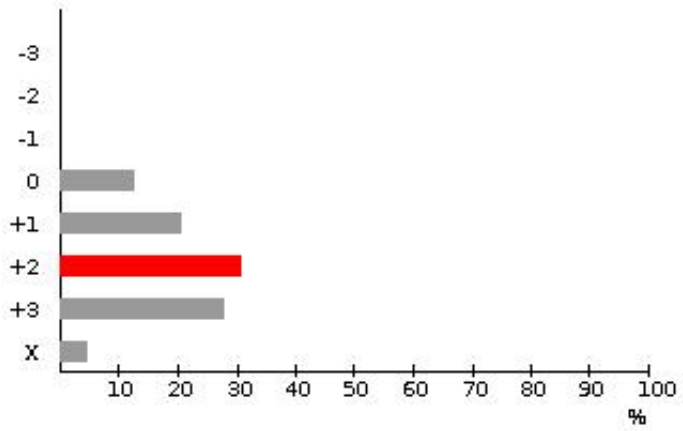
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I track my working hours, so the reported hours of work is exact. I should also mention that the topic was completely new for me and I had not done the basic course.
-mostly exploring on my own.
-Not evenly spread.

Learning experience

The learning objectives helped me understand what I was expected to achieve (S7)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



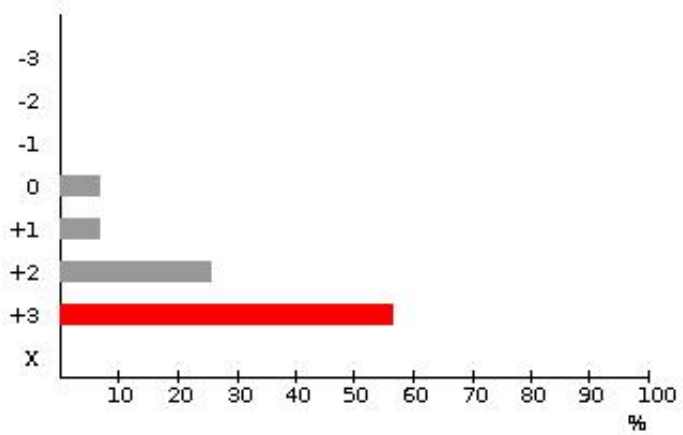
number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
5	13,2%	0
8	21,1%	+1
12	31,6%	+2
11	28,9%	+3
2	5,3%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I usually do not remember the objectives
-I had my own learning objectives

I worked with interesting issues (S1)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
3	7,9%	0
3	7,9%	+1
10	26,3%	+2

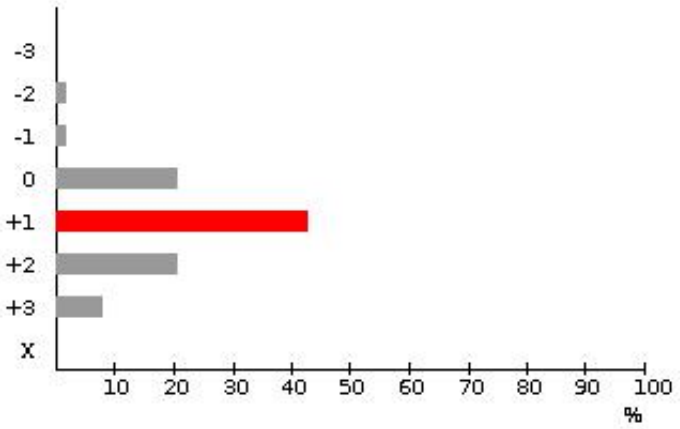
22	57,9%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-The projects were very well designed.
-Very interesting projects!
-I find the subject of the course very interesting from a practical and a theoretical point of view.

I regularly spent time to reflect on what I learned (S18)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



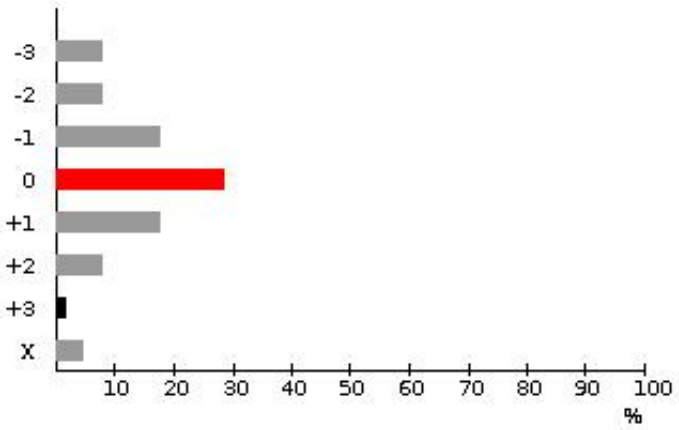
number	distribution	answer choice
0	0%	-3
1	2,7%	-2
1	2,7%	-1
8	21,6%	0
16	43,2%	+1
8	21,6%	+2
3	8,1%	+3
0	0%	X

Average (for numeric-answers): 0
37 has answered of 82 (45%)
Maximum number of choices: 1

Comment:

-yes, and I didn't have enough time to do so.

Out of interest I explored parts of the topic on my own (S2)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



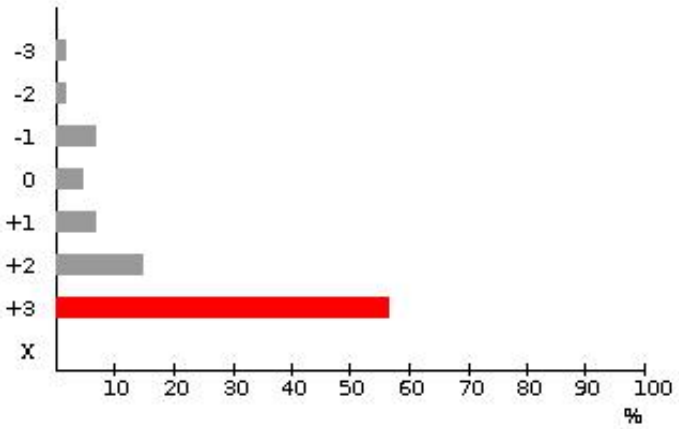
number	distribution	answer choice
3	8,1%	-3
3	8,1%	-2
7	18,9%	-1
11	29,7%	0
7	18,9%	+1
3	8,1%	+2
1	2,7%	+3
2	5,4%	X

Average (for numeric-answers): 0
37 has answered of 82 (45%)
Maximum number of choices: 1

Comment:

-There was really no time to do so.
-7 weeks are not enough to explore on your own. I wish I had more time.
-Obviously useful knowledge

My background knowledge was sufficient to follow the course (S17)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
1	2,6%	-3
1	2,6%	-2
3	7,9%	-1
2	5,3%	0
3	7,9%	+1

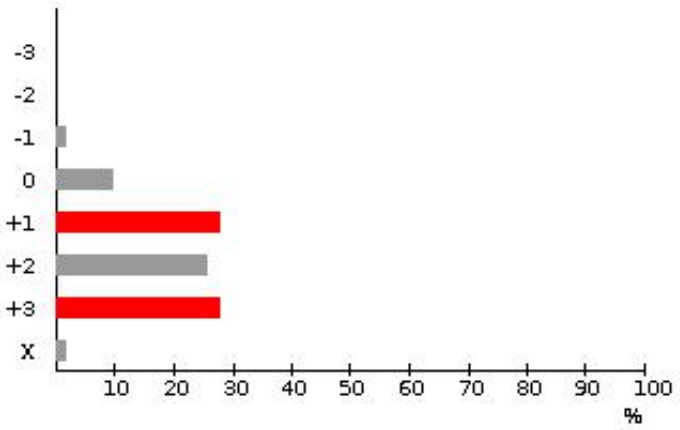
6	15,8%	+2
22	57,9%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-Hadn't read any optimization before, the basic course would have helped me I guess.
-I had not done the basic course! However it was still manageable with some self study.
-I studied SF1811 in the preceeding peroid.
-I had not taken a basic course in optimisation, consequently I was not at ease with the language. On the other hand, the mathematics were not to demanding.

I felt togetherness with other course participants (S5)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



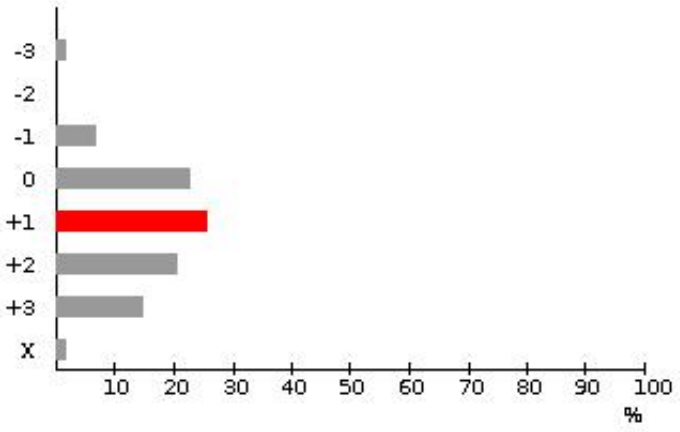
number	distribution	answer choice
0	0%	-3
0	0%	-2
1	2,6%	-1
4	10,5%	0
11	28,9%	+1
10	26,3%	+2
11	28,9%	+3
1	2,6%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-Mixing up groups randomly was an interesting idea!
I did the course as a PhD student and we were just mixed with other PhD students. I am not sure if this was a good way of doing it!
-Since I had problem with my first project group I can not give more than 1 on this statement. Part from that I strongly agrees with the statement.
-I had great fun working on the projects with people I had not met before!

I regularly received feedback that helped me see my progress (S14)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



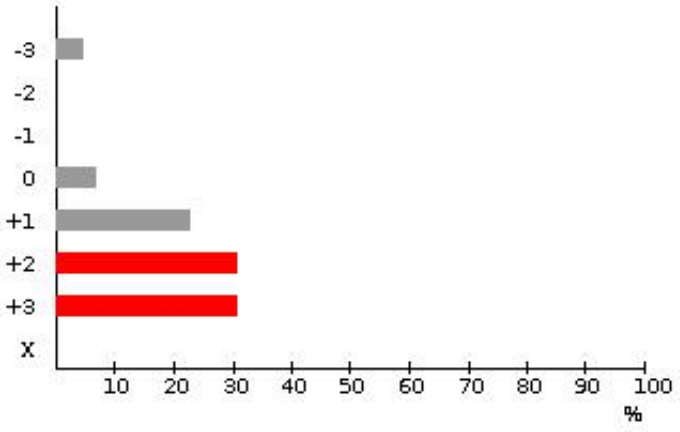
number	distribution	answer choice
1	2,6%	-3
0	0%	-2
3	7,9%	-1
9	23,7%	0
10	26,3%	+1
8	21,1%	+2
6	15,8%	+3
1	2,6%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I did not ask for this, but I believe that you guys were very helpful if one needed this.

The course was challenging in a stimulating way (S4)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
2	5,3%	-3
0	0%	-2
0	0%	-1
3	7,9%	0
9	23,7%	+1
12	31,6%	+2

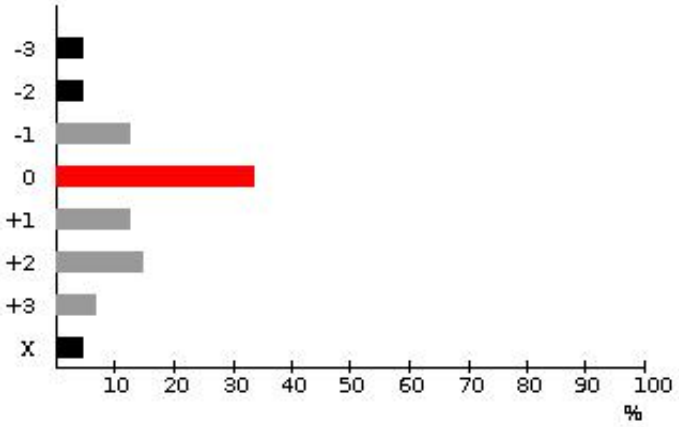
12	31,6%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-My only purpose of taking the course was to get challenged! I think the course was challenging and stimulating.
-It is always a challenge to learn new things.

I had opportunities to choose what I was going to do (S20)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



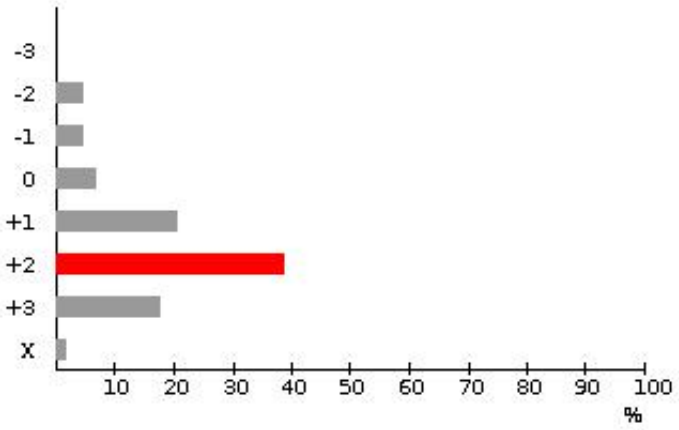
number	distribution	answer choice
2	5,3%	-3
2	5,3%	-2
5	13,2%	-1
13	34,2%	0
5	13,2%	+1
6	15,8%	+2
3	7,9%	+3
2	5,3%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I don't know

I understood what the teachers were talking about (S9)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



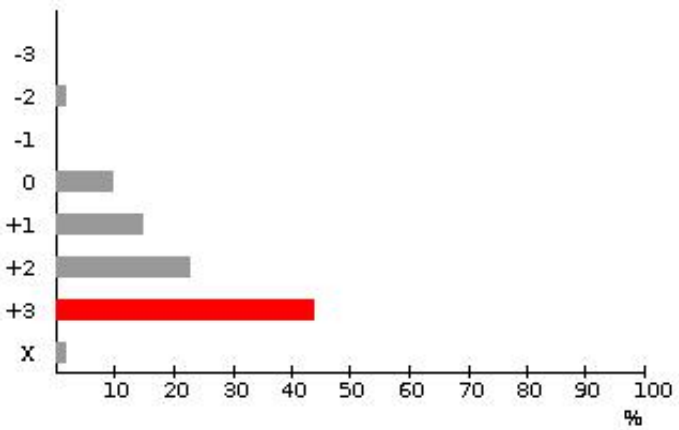
number	distribution	answer choice
0	0%	-3
2	5,3%	-2
2	5,3%	-1
3	7,9%	0
8	21,1%	+1
15	39,5%	+2
7	18,4%	+3
1	2,6%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I think presentations can be improved! To me it sounded that presentations are more or less just statement of problems without really understanding how to solve them. Besides, I found it confusing, when the teacher went back and forth on the slides. I learned 90% of the topics from self study and also working together with my friends.
-I followed the ideas, however I was not always comfortable with the notation. This was mostly due to me not having taken a basic course in optimisation.

Understanding of key concepts was given high priority (S11)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
0	0%	-3
1	2,6%	-2
0	0%	-1

4	10,5%	0
6	15,8%	+1
9	23,7%	+2
17	44,7%	+3
1	2,6%	X

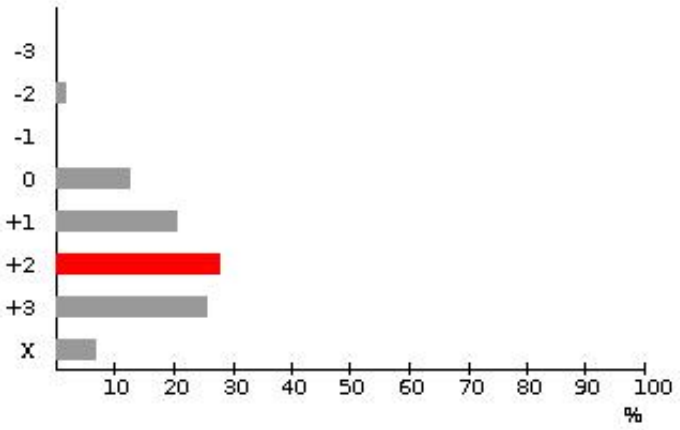
Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-Axel did a great job as teaching assistant.
-I think the proofs/derivations of the theory questions were very good, since a lot of the applications could be derived directly from them.
-The main problem i think is the lack of example for critical part like DWI dexomposition where we need did a full example with a changement of basis. It would be great to see this.
-not really, a lot of the result were given without real proof

---

I could practice and receive feedback without any grading being done (S15)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



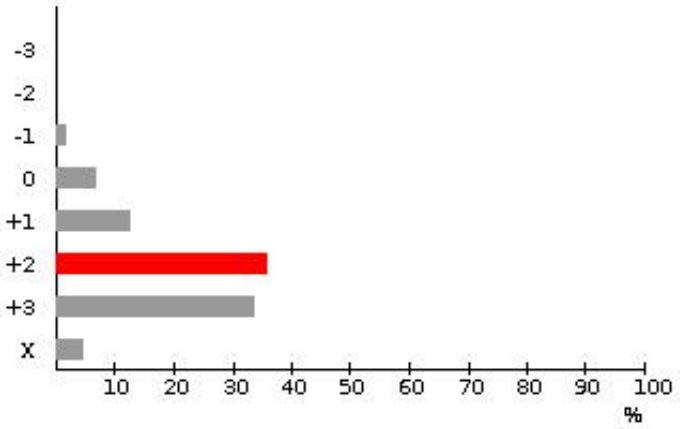
number	distribution	answer choice
0	0%	-3
1	2,6%	-2
0	0%	-1
5	13,2%	0
8	21,1%	+1
11	28,9%	+2
10	26,3%	+3
3	7,9%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-I don't know

The course activities helped me to reach the learning objectives efficiently (S12)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



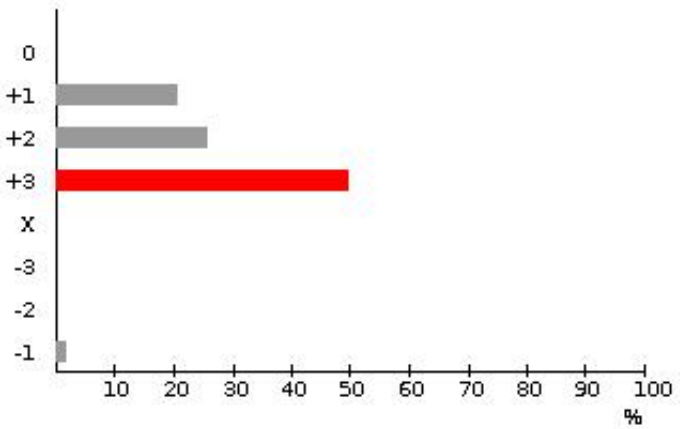
number	distribution	answer choice
0	0%	-3
0	0%	-2
1	2,6%	-1
3	7,9%	0
5	13,2%	+1
14	36,8%	+2
13	34,2%	+3
2	5,3%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-As before, I did not remember the learning objectives.
-Very good exercise classes, they helped alot!

I was able to learn by collaborating and discussing with others (S21)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
0	0%	-3
0	0%	-2
1	2,6%	-1
0	0%	0
8	21,1%	+1

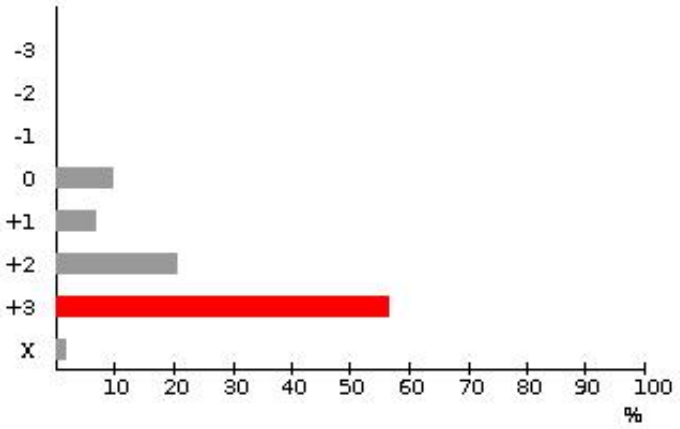
10	26,3%	+2
19	50%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-The projects contributed a lot to this matter.
-the discussion during the assignment workshop were helpful. also, I usually discuss with some friends how were taking the course with me.

The atmosphere in the course was open and inclusive (S6)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)

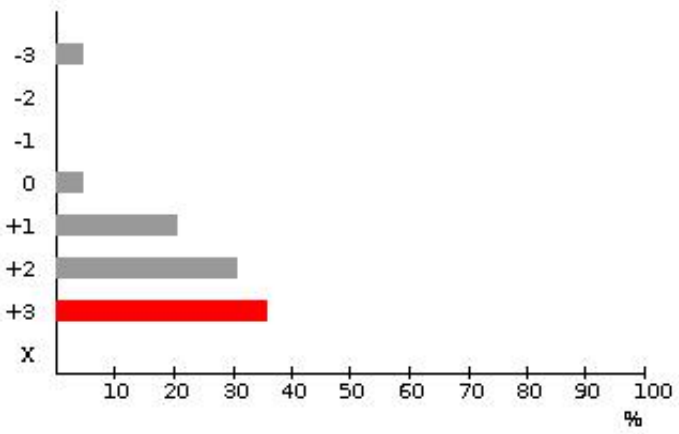


number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
4	10,5%	0
3	7,9%	+1
8	21,1%	+2
22	57,9%	+3
1	2,6%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

I was able to learn in a way that suited me (S19)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)

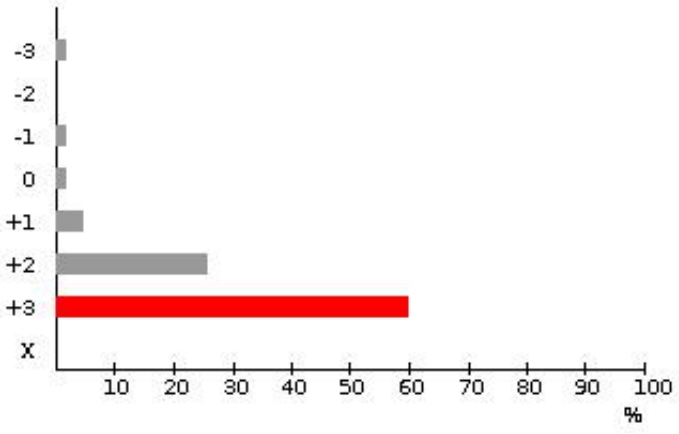


number	distribution	answer choice
2	5,3%	-3
0	0%	-2
0	0%	-1
2	5,3%	0
8	21,1%	+1
12	31,6%	+2
14	36,8%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

I understood how the course was organized and what I was expected to do (S8)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
1	2,6%	-3
0	0%	-2
1	2,6%	-1
1	2,6%	0
2	5,3%	+1
10	26,3%	+2
23	60,5%	+3

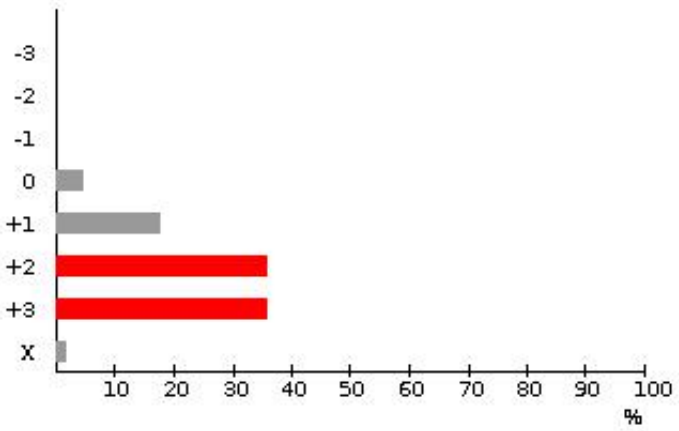
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-Very good organization.

I was able to learn by using concrete examples that I could relate to (S10)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



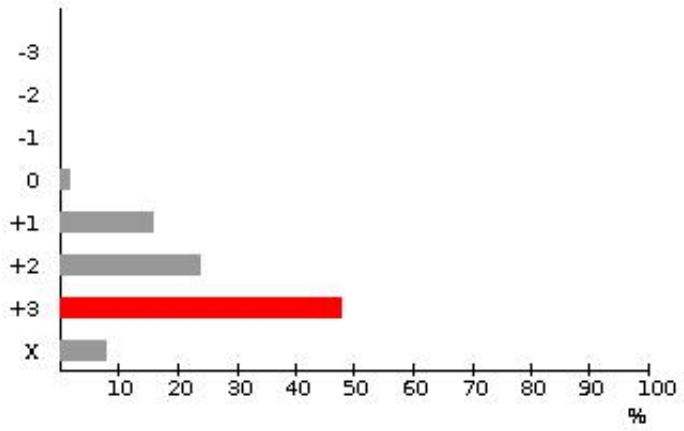
number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
2	5,3%	0
7	18,4%	+1
14	36,8%	+2
14	36,8%	+3
1	2,6%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-the 2 project were interesting I wish we had more

I was able to get support if I needed it (S22)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



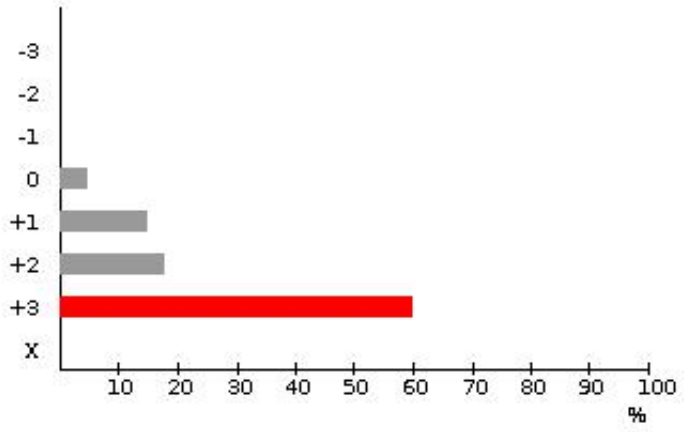
number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
1	2,7%	0
6	16,2%	+1
9	24,3%	+2
18	48,6%	+3
3	8,1%	X

Average (for numeric-answers): 0
37 has answered of 82 (45%)
Maximum number of choices: 1

Comment:

-I didn't need support. So I don't know.

The assessment on the course was fair and honest (S16)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



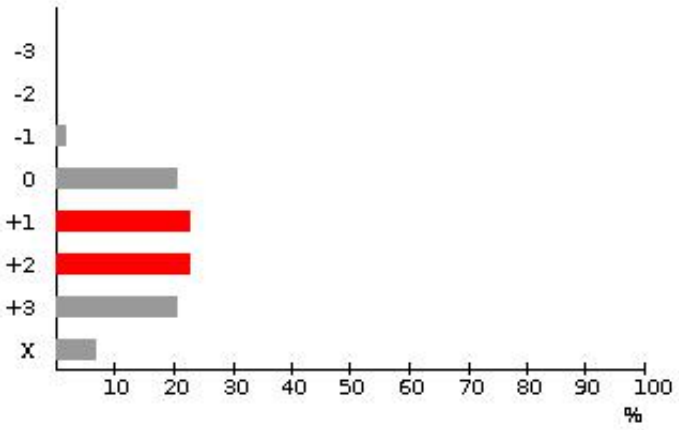
number	distribution	answer choice
0	0%	-3
0	0%	-2
0	0%	-1
2	5,3%	0
6	15,8%	+1
7	18,4%	+2

23	60,5%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

I could learn by trying out my own ideas (S3)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



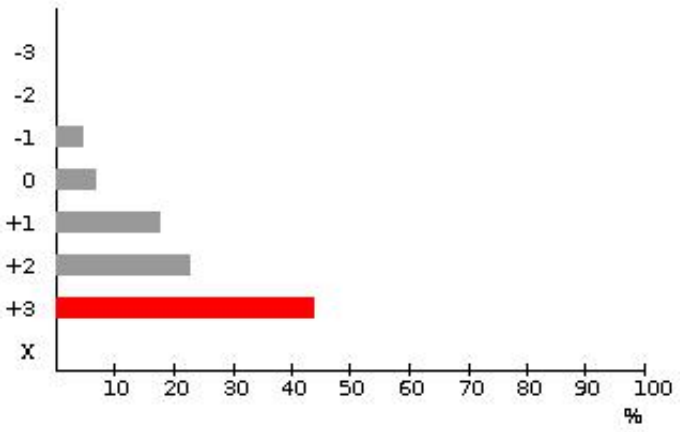
number	distribution	answer choice
0	0%	-3
0	0%	-2
1	2,6%	-1
8	21,1%	0
9	23,7%	+1
9	23,7%	+2
8	21,1%	+3
3	7,9%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-yes, even though I didn't had feedback for some of them.

I understood what I was expected to learn in order to get a particular grade (S13)
(Scale: -3: No, I strongly disagree with... 0: I am neutral to... +3: Yes, I strongly agree with the statement)



number	distribution	answer choice
0	0%	-3
0	0%	-2
2	5,3%	-1
3	7,9%	0
7	18,4%	+1
9	23,7%	+2
17	44,7%	+3
0	0%	X

Average (for numeric-answers): 0
38 has answered of 82 (46%)
Maximum number of choices: 1

Comment:

-Sure the grading system is fair and clear.

General questions

What was the best aspect of the course?

23 has answered of 82 (28%)

Comment:

-To learn how to solve linear programs.
-The organization and teachers
-Projects were really good, relevant and you learned some of the course content as well. I also liked that the exam was focused on the key concepts and not on details of a certain problem.
-Projects are very interesting and I really liked the last part of the course.
-Doing the theory questions that would enable one to understand the other exercises in the exam in a good way
-the thing that it was very well structured. The lecture notes were of much help
-The projects were fun and excellent for learning modeling.
-Good projects
-That there is a separation between modeling and solving. This is by far one of the best experiences I've had when it comes to efficient learning in combination with a hands-on experience.
-Interesting subject and good course structure
-learning by doing
-Using the learnt modeling methods on project works.
-The projects were a lot of fun and I especially enjoyed the second one where I got to model the robot moving through a corridor. It was very cool to see applications of the course in a context where at least I wouldn't expect it to.
-The exercise sections.
-The projects enable us to really learn how to model a real problem into a mathematical one.
-The course was more applied than I expected in the beginning but it turned out to be very interesting and stimulating.
-The projects
-I thought it was interesting to have the projects, and i also liked that The theory was concize but easy to understand in dept, it was really good to have the theory questions before each class! Thubs up!

-It aas a very good overview of linear optimization. I really enjoyed the different projects and the discussion after.
-In this course, students will have opportunity to do two projects quite related to theoretical knowledge that the professor taught in class and that the teacher gave lecture during the exercise session. This allows us to understand the core concepts of how we model the optimization problems and to learn new, useful programming language in Mathematical field. The projects seem hard since they are designed in the way to challenge the students, but however students are easy to raise questions to the professor and to the teacher during each session. Hence, all students can easily get pieces of advice in order to continually work on the projects.
-The GAMS projects
-Finally a course were we can se a clear link with real life application
-Projects

What would you suggest to improve?
20 has answered of 82 (24%)

Comment:

-I haven't read the basic course, so the course went on a little bit faster than I could keep up with in the beginning.
-it was too theoretical in some lectures
-Do the theory questions before actually starting to learn how to compute etc
-I did not like the book. However, that may be because I did not find the theory that interesting. Or it could be the other way around, I am not sure. However, the book was not really needed, since most theory was handled during the lectures.
-Explain more theory questions during lessons. It is more likely that we will learn them correctly then.
-More concrete outline on some things. It would be nice to have a very specific structure like: "Theory" --> "Method" --> "Solve example problem", in the same lecture.
-Since it is named "applied" it would be nice with some applied exercises on the exam (even though the projects were "applied").
-Posting, before the exercise session,which exercises will be done, in order to enable students to try on them.
-More practical examples in order to make it really 'applied'.
-I thought the projects and the final exam didn't really relate which came as a surprise when I sat down to study for the finals. Since I got the highest mark on both projects I expected to have a pretty good idea of what the exam would be like but instead I thought they were very different.
-Can not think of anything.
-Nothing, good course!
-Maybe something more in gams... By I am am in general happy about the course.
-Maybe more exercise sessions.
-Find a bit more different example, go a bit faster during exercise session. But in general both of the teachers are really good!
-Project:
Some projects such as the optimal controller are very practical in terms of applications from my perspective. It would be great for students to get almost all viable projects.

Teaching during exercise session:
The teacher in the exercise session occasionally wrote the notes on the blackboard with such a small size that students cannot see if they sat too distant from the blackboard.
-More theory, I know that it is a project based course but at the same time I like to have a more general view to the subject.
Some recommended exercise (4 or 5 not more) for each part of the course that address not only how to use the algorithms but also some theoretical questions.
Having a set of theory question for the exam is not good a lot of student learn them instead of understanding them.
Running the course over 2 period would help everybody appreciate the content.
-There is a too small difference between basic problem and the "advanced" ones. (Perhaps it is because gams made it easy)
-I, personally, found the lecture notes not enough to understand concept. Extended lecture notes would help me a lot.
-I never understood if the exercises done during the exerciece sessions was able in the course material? Also it would have been nice having the solutions to the exercises which we went through during exercises. Now the exercises was just copying the whiteboard. No thinking and only little learned.

What advice would you like to give to future course participants?

24 has answered of 82 (29%)

Comment:

-Make sure you know the theory questions by heart, it helps a lot to understand other problems too.
-Read the book and solve the exercises!
Do the projects as they are fun and rewarding.
Discuss your understanding with other students!
You don't need to write down everything at the exercise sessions. Put your effort for learning the concepts and methods.
-Study

Study
-If you are a PhD student and have not passed the basic course and you're not related to applied math, Good luck!
-Focus on theory question it is worth it
-The theory questions are central to the course, at least a few of them. Get familiar.
-Start early with projects
-Listen to Anders and follow his advice! Everything he says is useful, specially when you think that he's talking about something not so important. Don't be afraid to ask a zillion questions, Anders will not stop until you understand.
-Take the basic course prior to this one and study hard
-You don't have to take the basic course in order understand what's going on in this one. However, it's good to be familiar with the terminology. Just watch some videos on optimization online before starting this course, read the course material, participate in lectures and exercises, discuss with other course participants during the course, and you'll be fine.
-Enjoy projects and try your own ideas
-Go to the lectures, AF is really fun to listen to.
-To study old exams from the start since just keeping up with the projects isn't enough
-Study hard and do exercises and theory questions from the start.
-Go to lectures and exercise sessions, they both are really helpful!
-1. Start the projects quite early since each project takes time to interpret the modelling to capture the behavior of the situation. If you get stuck with the modelling, then don't hesitate to discuss the issues with the professor and the teacher in the exercise session.

2. Try to do theory questions, i.e. solve them before each lecture since this will give you the overall picture of optimization theory and methods.
-Work theoretical question during the course this is one of the best way to understand it.
The the book for additionnal content
Start working early and the exam will be easy
-Focus on the theory questions... If you do them ahead the course is quite easy to follow.
-Focus on the projects during the course and when the projects are done focus on the exam.
-Do the theory questions from the start to keep up with the lectures. It will help your understanding a lot.
-this course is not about writing GAMS code there is more to linear programming then that. This is not a computer science class, so try to appreciate the practical and theoretical aspect of the course if you want to enjoy your time. (doing exercise regularly is helpful for a deeper understanding of the concepts)
-Learn danzig wolf
-Look at the theory questions and solve them, because you are going to solve them later anyway for the exam.
-If you have not taken a basic course in optimisation, immediately start familiarizing yourself with the simplex method and the notation that goes with. This is needed to follow the lectures.

Is there anything else you would like to add?
15 has answered of 82 (18%)

Comment:

-I didn't work as much as I should
-Both Anders and Axel were great.
-Great exercise leader and fun course.
-Great Job to Axel as well, he is doing a great job. Maybe sometimes he speaks too fast, but it's OK! :) Keep it up guys!
-very organized course.
-I loved the exam examples about not so reliable AF.
-no
-Thank you for a good and well structured course!
-This is the first time in had such a good teacher assistant, really clear and efficient.
One of my best course in kth.
-A very well organised course! Special thanks to Alex for great tutorials!
-Big thanks to the teaching assistant! He was really motivated and did a great job, it is quite difficult to manage this long exercises on a two hours class and I think he was oustanding.
-It was a good and interesting course. I look forward to the next course, "Applied nonlinear optimization".
-No.
-:Kappa:
-I had great fun working on the projects!

Optimization and Systems Theory

SF2812 Applied Linear Optimization, 7.5hp, 2014/2015

Instructor and examiner

Anders Forsgren (andersf@kth.se), room 3533, Lindstedtsv. 25, tel 790 71 27.
Office hours: Monday 11-12. (Or by agreement.)

Exercise leader and project leader

Axel Ringh (aringh@kth.se), room 3734, Lindstedtsv. 25, tel. 790 66 59.
Office hours: By agreement.

Course material

(The course material is available at Bilda in the form of pdf files.)

- ***Linear and Nonlinear Optimization***, second edition, by I. Griva, S. G. Nash och A. Sofer, SIAM, 2009.
  Information on how to order the book can be found here.
- ***Exercises in applied linear optimization, 2014/2015***. Available at Bilda.
- ***Lecture notes in applied linear optimization, 2014/2015***. May be downloaded from this web page, see the schedule below. Also available at Bilda.
- ***Supplementary course material in applied linear optimization, 2014/2015***. Available at Bilda.
- ***Theory questions in applied linear optimization, 2014/2015***. Available at Bilda.
- ***GAMS, A user's guide***. May be downloaded from the GAMS web site.
- ***GAMS***. GAMS is installed in the KTH linux computer rooms. It may also be downloaded from the GAMS web site for use on a personal computer.
- Two project assignments that are handed out during the course, February 3 and February 17 respectively.

Additional notes that may be handed out during the course are also included.

Course goals

After completed course, the student should be able to:

- explain fundamental concepts of linear programming and integer linear programming;
- explain how fundamental methods for linear programming and integer linear programming work;
- illustrate how these methods work by solving small problems by hand calculations;
- starting from a suitably modified real problem, formulate a linear program or an integer linear program; make a model in a modeling language and solve the problem;
- analyze the solutions of the optimization problem solved, and present the analysis in writing as well as orally;
- interact with other students when modeling and analyzing the optimization problems.

Examination

The examination is in two parts, projects and final exam. To pass the course, the following requirements must be fulfilled:

- Pass project assignment 1, with presence at the compulsory presentation lecture on Tuesday February 17, and presence at the following dicussion session.
- Pass project assignment 2, with presence at the compulsory presentation lecture on Tuesday March 3, and presence at the following dicussion session.
- Pass final exam.

Course registration

Due to the project based nature of this course, students must register no later than January 31. Registration lists will be circulated at the initial lectures. Each student must give an e-mail address where he/she can be reached.

Project assignments

The project assignments are performed in groups, where the instructor determines the division of groups. This division is changed between the two assignments. The assignments are carried out by the modeling language GAMS. The project assignments ***must*** be carried out during the duration of the course and completed by the above mentioned presentation lectures. Presence at the presentation lectures is compulsory. For passing the projects, the following requirements must be fulfilled:

- At the beginning of the presentation lecture, each group must hand in a well-written report which describes the exercise and the group's suggestion for solving the exercise. Suitable word processor should be used. The report should be on a level suitable for another participant in the course who is not familiar with the group's specific problem.
- When handing in the report, each student should append an individual sheet with a brief self-assessment of his/her contribution to the project work, quantitatively as well as qualitatively.
- At the presentation lecture, all assignments will be presented and discussed. Each student is expected to be able to present the assignment of his/her group, the modeling and the solution. In particular, each student is expected to take part in the discussion. The presentation and discussion should be on a level such that students having had the same assignment can discuss, and students not having had the same assignment can understand the issues that have arisen and how they have been solved.
- Each group should make an appointment for a discussion session with the course leaders. There is no presentation at this session, but these sessions are in the form of a 20 minutes question session, one group at a time. There will be times available the days after the presentation session. One week prior to the presentation lecture, a list of available times for discussion sessions will be made available at Doodle, reachable from the course home page. Each group should sign up for a discussion session prior to the presentation lecture.

Each project assignment is awarded a grade which is either fail or pass with grading E, D, C, B and A. Here, the mathematical treatment of the problem as well as the report and the oral presentation or discussion is taken into account. Normally, the same grade is given to all members of a group

Each group must solve their task independently. Discussion between the groups concerrning interpretation of statements etc. are encouraged, but each group must work independently without making use of solutions provided by others. All groups will not be assigned the same exercises.

Final exam

The final exam consists of five exercises and gives a maximum of 50 points. At the exam, the grades F, Fx, E, D, C, B and A are awarded. For a passing grade, normally at least 22 points are required. In addition to writing material, no other material is allowed at the exam. Normally, the grade limits are given by E (22-24), D (25-30), C (31-36), B (37-42) and A (43-50).

The grade Fx is normally given for 20 or 21 points on the final exam. An Fx grade may be converted to an E grade by a successful completion of two supplementary exercises, that the student must complete independently. One exercise among the theory exercises handed out during the course, and one exercise which is similar to one exercise of the exam. These exercises are selected by the instructor, individually for each student. Solutions have to be handed in to the

instructor and also explained orally within three weeks of the date of notification of grades.

The final exam is given Wednesday March 18 2015, 8.00-13.00, in rooms L51 and L52.

Final grade

By identitying A=7, B=6, C=5, D=4, E=3, the final grade is given as

round((grade on proj 1) + (grade on proj 2) + 2 * (grade on final exam)) / 4),

where the rounding is made to nearest larger integer in case of a tie.

Preliminary schedule

"L" means lecture, "E" means exercise session, "P" means project sesstion.

Type	Day	Date	Time	Room	Subject
L1.	Tue	Jan 20	15-17	M33	Introduction. Linear programming models. (pdf)
L2.	Wed	Jan 21	13-15	L51	Linear programming. Geometry. (pdf)
L3.	Thu	Jan 22	13-15	M33	Lagrangian relaxation. Duality. LP optimality. (pdf)
L4.	Mon	Jan 26	15-17	M33	Linear programming. The simplex method. (pdf)
E1.	Tue	Jan 27	13-15	L52	Linear programming. The simplex method.
L5.	Wed	Jan 28	13-15	M33	More on the simplex method. (pdf)
E2.	Thu	Jan 29	13-15	L52	Linear programming. The simplex method.
P1.	Mon	Feb 2	15-17	Q36	Introduction to GAMS. (pdf)
P2.	Tue	Feb 3	13-15	Orange	GAMS excercise session.
L6.	Wed	Feb 4	13-15	M33	Stochastic programming. (pdf)
E3.	Thu	Feb 5	13-15	L52	Stochastic programming.
L7.	Mon	Feb 9	15-17	L52	Interior methods for linear programming. (pdf)
E4.	Tue	Feb 10	13-15	M33	Interior methods for linear programming.
L8.	Wed	Feb 11	13-15	M33	Integer programming models. (pdf)
L9.	Thu	Feb 12	13-15	M33	Branch-and-bound. (pdf)
L10.	Mon	Feb 16	15-17	L52	Decomposition and column generation. (pdf)
P3.	Tue	Feb 17	13-15	M33	Presentation of project assignment 1.
E5.	Wed	Feb 18	13-15	M33	Integer programming.
E6.	Mon	Feb 23	15-17	M33	Decomposition and column generation.
L11.	Tue	Feb 24	13-15	M33	Lagrangian relaxation. Duality. (pdf)
E7.	Wed	Feb 25	13-15	L52	Lagrangian relaxation. Duality.
L12.	Mon	Mar 2	15-17	Q33	Subgradient methods. (pdf)
P4.	Tue	Mar 3	13-15	L52	Presentation of project assignment 2.
E8.	Wed	Mar 4	13-15	M33	Subgradient methods.

Mapping of exercises to lectures

The sections in the exercise booklet may roughly be mapped to the lectures as follows:

- 1. The simplex method. After L4.
- 2. Sensitivity analysis. After L4.
- 3. Interior point methods. After L7.
- 4. Decomposition and column generation. After L10.
- 5. Linear programming - remaining. After L7.

- 6. Stochastic programming. After L6.
- 7. Formulation - integer programming. After L8.
- 8. Lagrangian relaxation and duality. After L11.
- 9. Subgradient methods. After L12.

Overview of course contents

- **Linear programming**
  Fundamental LP theory with corresponding geometric interpretations. The simplex method. Column generation. Decomposition. Duality. Complementarity. Sensitivity. Formulations of LPs. Interior methods for linear programming, primal-dual interior methods in particular. (Chapters 4-7 in Griva, Nash and Sofer, except 5.2.3, 5.2.4, 5.5.1, 6.5, 7.5, 7.6. Chapter 9.3 in Griva, Nash and Sofer. Chapter 10 in Griva, Nash and Sofer, except 10.3, 10.5.)
- **Stochastic programming**
  Fundamental theory. (Supplementary course material.)
- **Integer programming**
  Formulations of integer programs. Branch-and-bound. Lagrangian relaxation and subgradient methods applied on integer programs with special structure. (Supplementary course material.)

Welcome to the course!

Course home page: http://www.math.kth.se/optsyst/grundutbildning/kurser/SF2812/.

Published by: Optimization and Systems Theory, KTH
Anders Forsgren, andersf@kth.se
Last updated: 2015-01-20