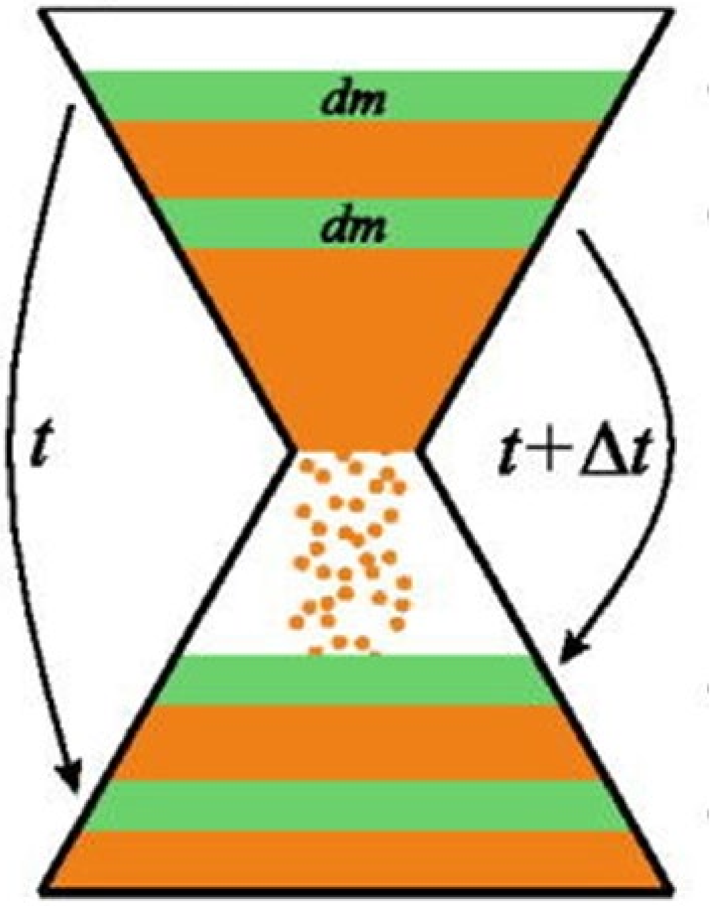
From Dublin descriptors to implementation in Bachelor labs

Paul Logman & Jaap Kautz | Landelijke natuurkundepracticumdag 2020

Universiteit Leiden
The Netherlands

Leiden Institute of Physics

Contents



© 2017 Sack, Pöschel

Motive

- Little change for many years
- Need for better preparation for BSc-project
- No more ‘cookbook labs’
- Better cohesion with other subjects

© 2013 James Rebanks

Step 1: Learning objectives

First challenge: brainstorm to set challenging and motivating learning objectives for the students.

Step 1: Learning objectives

First challenge: brainstorm to set challenging and motivating learning objectives for the students (~130):

e.g.

- *Students are able to use a cryostat.*
- *Students are able to calculate the error propagation from the statistical errors in their measuring equipment to the statistical error in their final results.*
- *Based on theory students are able to formulate a substantiated, falsifiable, and quantifiable hypothesis to their research question.*
- *Students are able to present their results in tables and graphs in a clear manner.*

Step 1: Learning objectives

Next challenge: to group all ~130 learning objectives in measurable entities:

5	**Research skills**
6	Students are able to perform an 80 hour research project independently, from first conception to presenting and reporting.
7	*Based on a specific problem students are able to write a measuring plan from which reasonably may be expected that it will deliver usab*
8	Students are able to translate a problem into a research question.
9	Based on a research question students are able to perform a literature research.
10	Students are able to distill information from scientific literature relevant to their own research.
11	Students are able to model a physical system based on physical theories.
12	Students are able to come up with their own research ideas, measuring methods and analysis strategies.
13	Based on theory students are able to formulate a substantiated, falsifiable, and quantifiable hypothesis to their research question.
14	Students are able to build simple simulations.
15	Students are able to calculate transfer functions.
16	Based on a research question students are able to design a fitting experimental setup.
17	Students are able to describe several measuring methods by which causes of known systematic errors can be minimised.
18	Based on the demands of their experimental setup students are able to write up specifications for the necessary apparatus.
19	Based on the specifications of apparatus students are able to choose which apparatus is most suited to their experiment.
20	Students are able to describe how to guarantee the safety of themselves and others during simple experiments.
21	Students are able to assess when they need help to guarantee the safety of an experiment.
22	*Based on a measuring plan students are able to write an analysis plan from which reasonably may be expected that it will deliver an ans*
28	*Students are able to write a datamanagement plan.*
34	*Students are able to independently collect trustworthy results from an experiment.*
81	*Students are able to independently and critically analyse an experiment.*
104	*Students are able to communicate their research and that of others in a structured and catchy manner, both written and verbally.*

Step 1: Learning objectives

Research
Measurement plan
Analysis plan
Measurement
Analysis
Communication

Next challenge: to group all ~130 learning objectives in measurable entities (Specific, Measurable, Attainable, Relevant, Time-based, Inspirational).

1. *Based on a problem students are able to write a measuring plan from which reasonably may be expected that it will deliver usable results.*
2. *Based on a measuring plan students are able to write an analysis plan from which reasonably may be expected that it will deliver an answer to the research question.*
3. *Students are able to independently collect trustworthy results from an experiment.*
4. *Students are able to independently and critically analyse an experiment.*
5. *Students are able to communicate their research and that of others in a structured and catchy manner, both written and verbally.*

Step 1: Learning objectives

Logman/Kautz (1-5) vs Etkina (A-G)	A represent in multiple ways	B devise and test	C modify	D design investigation	E collect and analyze data	F evaluate	G communicate
1 Measurement plan	X	X		X			
2 Analysis plan	X	X	X	X		X	
3 Measurement		X			X	X	
4 Analysis		X	X		X	X	
5 Communication	X						X

e.g.

3. Students are able to independently collect trustworthy results from an experiment

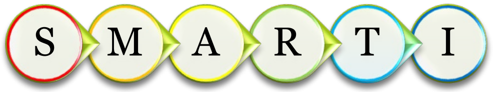
(Logman & Kautz, 2018)

B. Ability to devise and test a qualitative explanation or quantitative relationship

(Etkina, 2006)

Step 1: Learning objectives

Measurable learning objectives (recap):



1. *Based on a problem students are able to write a measuring plan from which reasonably may be expected that it will deliver usable results.*
2. *Based on a measuring plan students are able to write an analysis plan from which reasonably may be expected that it will deliver an answer to the research question.*
3. *Students are able to independently collect trustworthy results from an experiment.*
4. *Students are able to independently and critically analyse an experiment.*
5. *Students are able to communicate their research and that of others in a structured and catchy manner, both written and verbally.*

Step 1: Learning objectives

Final grouping gives us our main learning objective:

Students are able to perform an 80 hour research project independently, from first conception to presenting and reporting.

Step 1: Learning objectives

Dublin descriptors (very general)

A. Knowledge and understanding

B. Applying knowledge and understanding

C. Making judgements

D. Communication

E. Lifelong learning skills

Step 1: Learning objectives

Dublin descriptors – Domain Specific Reference Frame (more specific)

B. Applying knowledge and understanding

- Problem solving skills, Estimation skills
- Modelling skills
- Mathematical skills
- **Experimental skills**
- Computer skills
- Familiarity with basic and applied research

(B) APPLYING KNOWLEDGE AND UNDERSTANDING

	Specific competence	Description. On completion of the degree course, the student should
1, 5	Problem solving skills, Estimation skills	be able to frame, analyze and break down a problem in phases defining a suitable algorithmic procedure; be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems.
6	Modelling skills	be able to identify the essentials of a process/situation and to set up a working model of the same; be able to perform the required approximations; i.e. critical thinking to construct physical models.
2	Mathematical skills	be able to understand and master the use of the most commonly used mathematical and numerical methods.
4	Experimental skills	have become familiar with most important experimental methods and be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data; be able to scientifically report the findings.
	Computer skills	be able to use appropriate software, programming language, computational tools and methods in physical and mathematical investigations.
8	Familiarity with basic and applied research	acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

Step 1: Learning objectives (1st result)

Dutch Specific Reference Frame

-
-
-

Dublin descriptors

-
-
-

Our grouped learning objectives

-
-
-

Etkina's research abilities

-
-
-

Our specific learning objectives

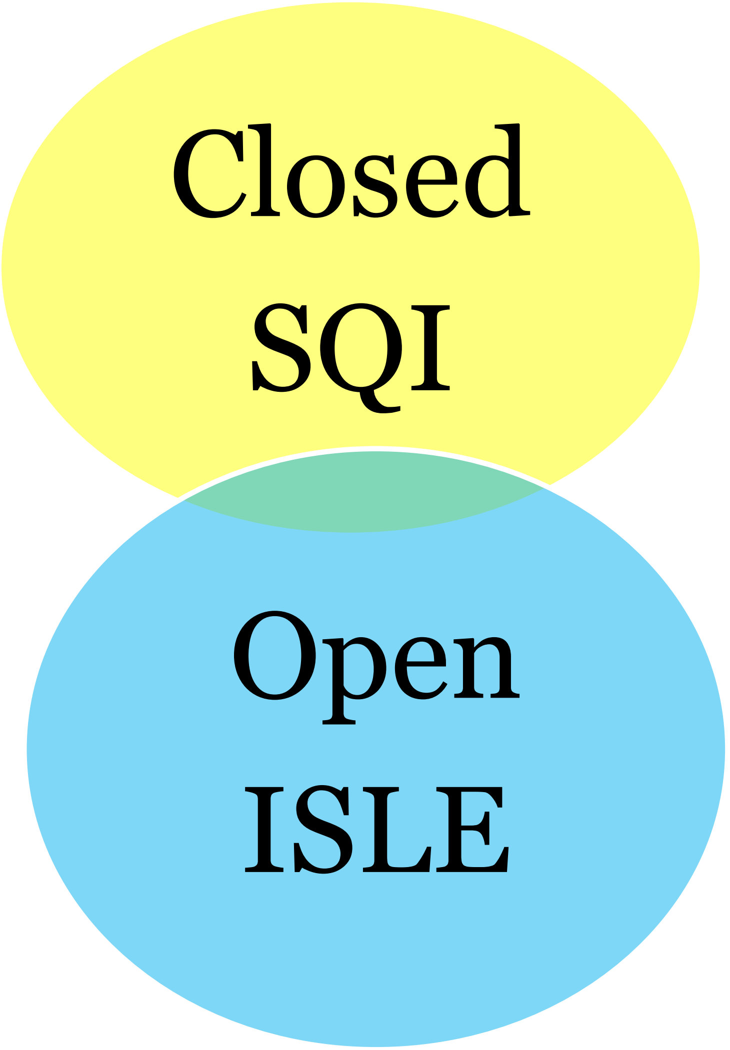
-
-
-
-

Step 2: Design principles from theory

The chosen practicals should provide a need for the student to learn what we want them to learn (Lijnse & Klaassen, Bulte)

1. Closed practicals to learn apparatus skills, analytical skills, necessary physics knowledge
2. Closed practicals follow SQI (*Structured Quantitative Inquiry*) method (Holmes)

3. Open practicals needed to learn research skills
4. Open practicals follow ISLE (*Investigative Science Learning Environment*) method (Etkina)



Step 3: Implementation year 1

Leiden university specific implementation: 6 courses of 1ECTS each & a 1 ECTS Presentation & Communication course

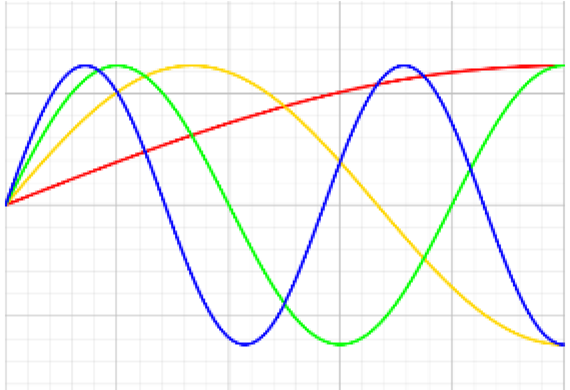
- Course 1 has been adapted the most, course 3 & 5 have been readapted last year
- Cohesion with departments

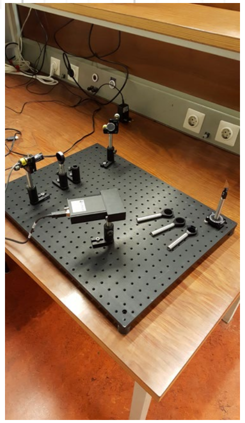
  (Biophysics & Soft matter, Quantum Mechanics & Optics) →

- Courses 1 & 2: Lab journal & Soft matter,
- Courses 3 & 4: Oscillations & Waves (no QM but CM in year 1),
- Courses 5 & 6: Optics

  (Cohesion with subjects (Classical Mechanics & Optics) → connect to physics knowledge)

- Courses 1, 3 & 5: closed SQI practicals on apparatus skills, analytical skills, necessary physics knowledge
- Courses 2, 4 & 6: open ISLE practicals to assess research skills





Step 4: Implementation year 2

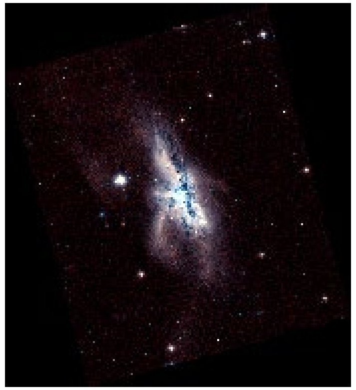
Leiden university specific implementation:

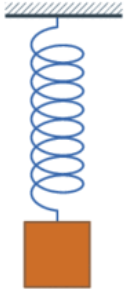
3 new courses of 1(+2)ECTS, 1(+4)ECTS & 2ECTS

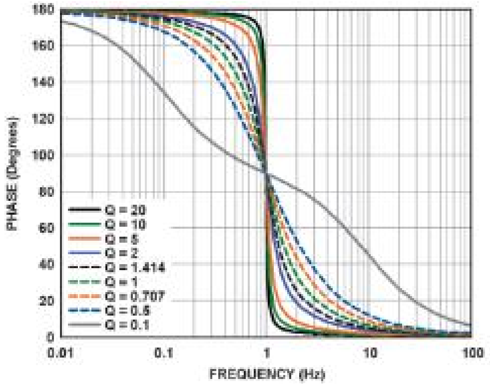
- Course 1: Fourier transform
- Course 2: 2D Fourier transform, Noise, Feedback, OpAmp
- Course 3: Feedback & Noise reduction

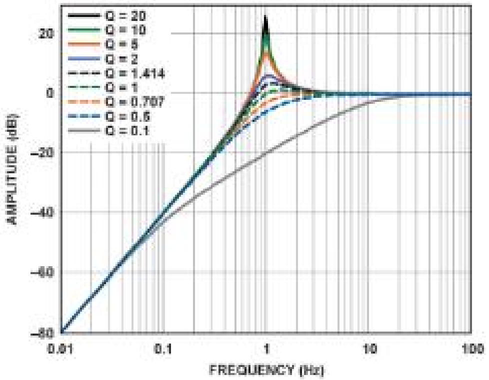
(Cohesion with subjects (Classical Mechanics & Optics) → connect to physics knowledge)

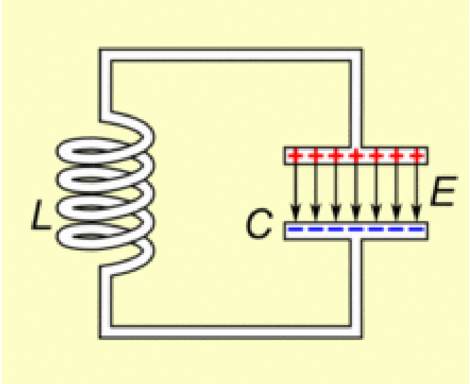
- Courses 1 & 2: closed SQI practicals on apparatus skills, analytical skills, necessary physics knowledge
- Course 3: open ISLE practicals to assess research skills











Step 5: Inspirational matrices in year 1 & 2

Course 4:

Oscillations & Waves

Oscillations & Waves	Water waves	Sound waves	Radio waves	Microwaves	Optical waves	Torsion waves	Pendula	Springs	Bars/tubes	Musical instruments
Deepening knowledge of eigenfrequencies en resonance (session 1 EN3)										
Deepening knowledge of interference (session 2 EN3)										
Deepening knowledge of standing waves (session 3 EN3)										
Refraction										
Total reflection										
Transmission										
Coupled harmonic oscillators										
Diffraction										
Dopplereffect										
2D- of 3D-oscillations or -waves										
Fourieranalysis										
Frequencyfilters										
Tunneling models										

Step 6: Results year 1

Theoretically primed students (not objective), overall enjoyment of the course remains the same (6.7 out of 10)

- **Students** – find the course challenging, saw the need for preparation and lab journal, independence in open practicals is appreciated, connection with theoretical courses is noted
- **Teaching-assistants** – wished they had had the course like this, mostly because of the addressed analytical skills, course has become more challenging
- **Teachers** – the course seems to run more by itself, better results on error analysis, better use of Python for analysis and data representation, EN6 teacher was in favour of planning one session less

Veel zelfstandigheid.

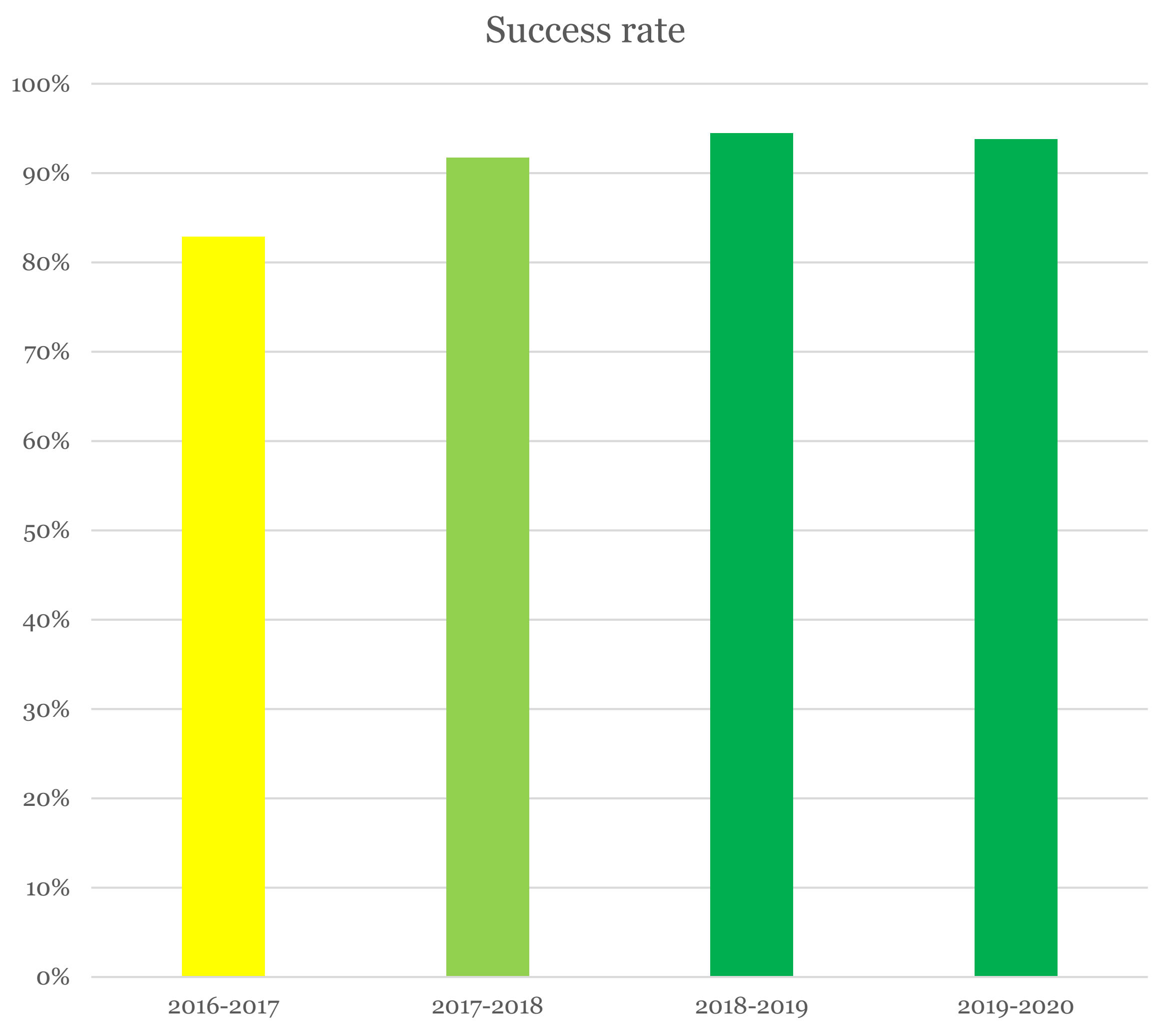
Practica en hoor colleges goed gecombineerd

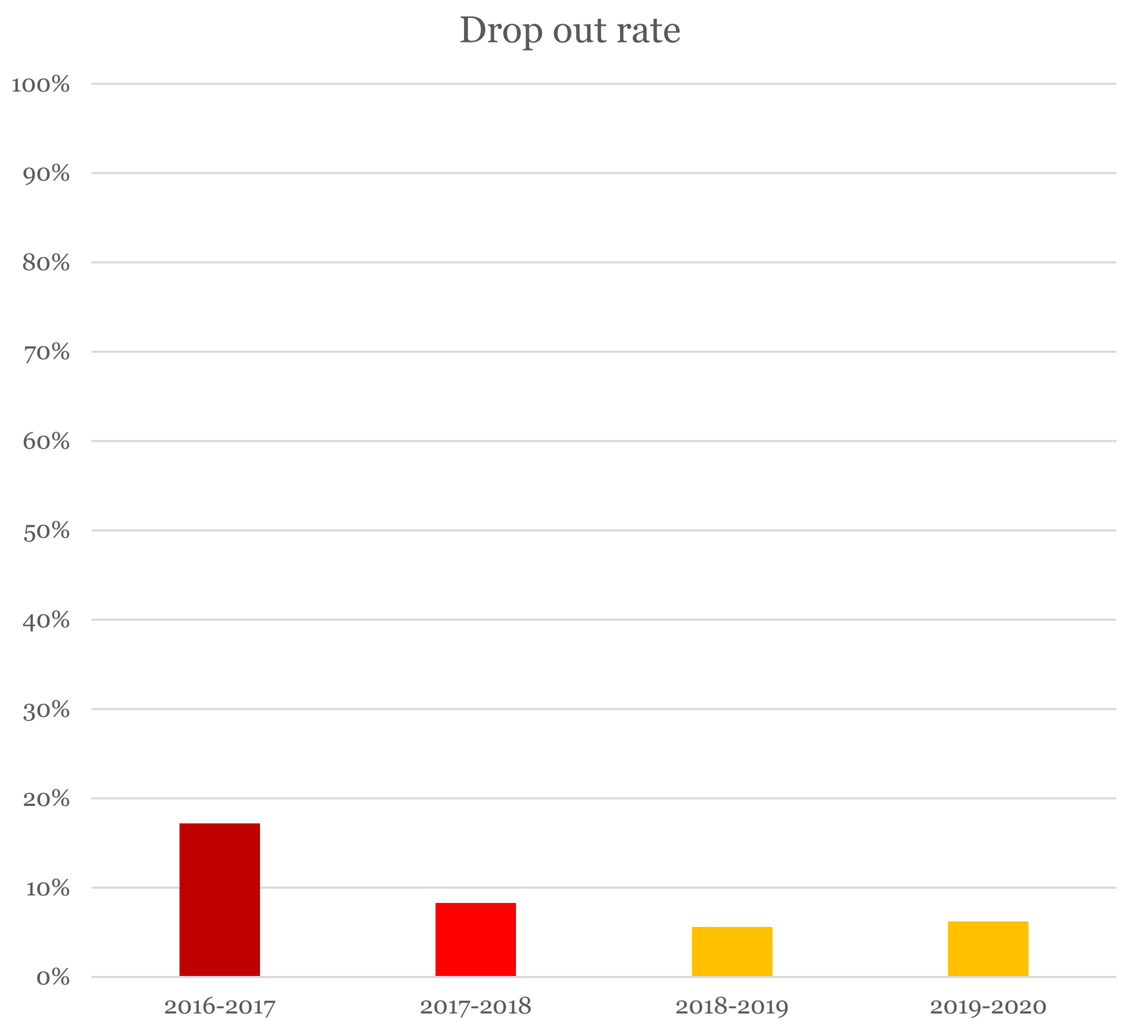
Het is goed uitdagend.

Laat goed zien dat voorbereiding belangrijk is

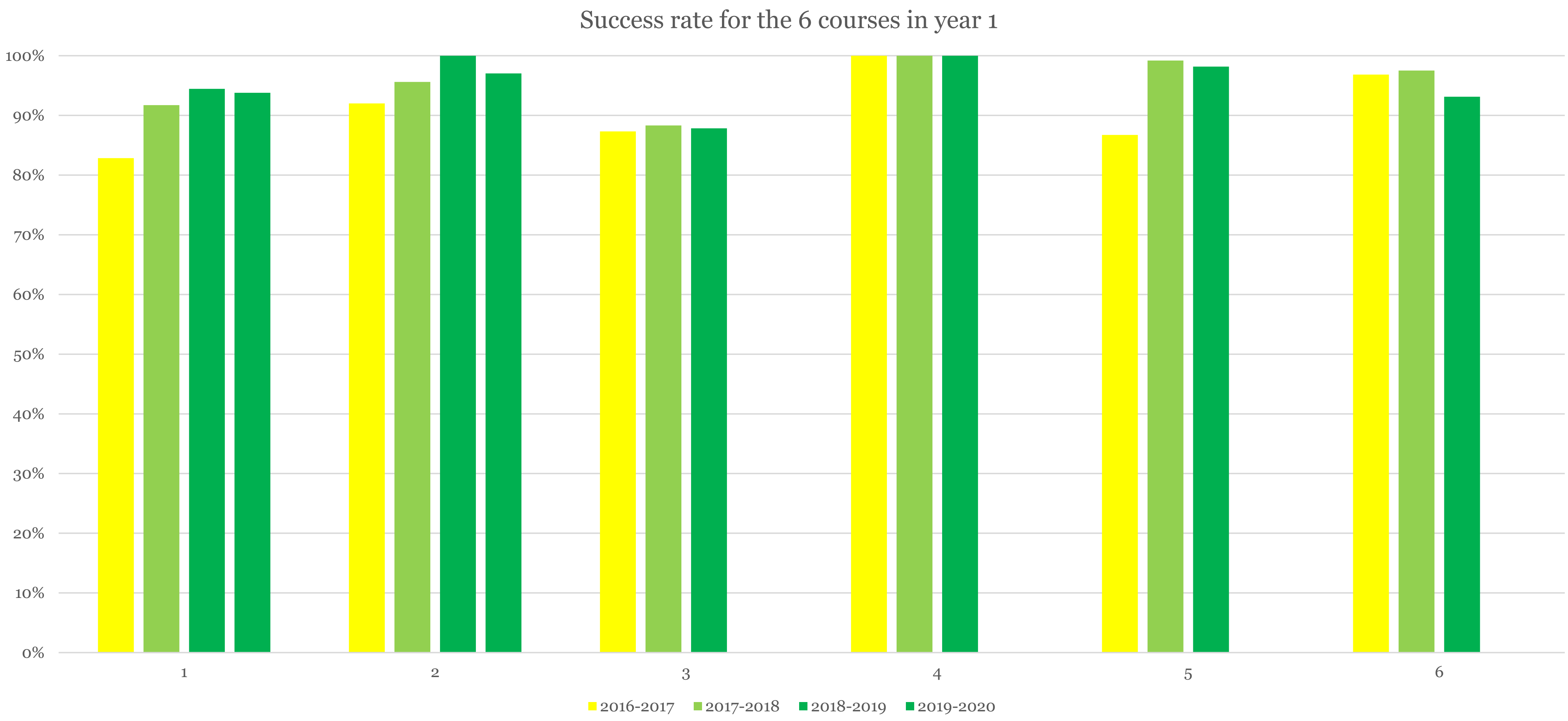
je leert goed werken met de meetapparatuur en python

Step 6: Results for 1st course in year 1





Step 6: Results for all courses in year 1



Step 7: Results year 2

- **Students** – find the course challenging, like the combination of theory and practicals, did not see the need for preparation and lab journal, independence in open practicals is appreciated, connection with theoretical courses is noted
- **Teaching-assistants** – combination with the use of Python is challenging, students less proactive during closed practicals, too many practicals per session, open practicals could focus more on theory
- **Teachers** – less need for preparation & lab journal in closed practicals, good use of Python for analysis and data representation, too many practicals per session, open practicals could focus more on theory

leuke onderwerp waar je dagelijks mee te maken hebt (vooral noise)

Niet genoeg tijd voor practica

Goede combinatie praktijk/theorie

Discussion

Year 1:

- Implementation started 2 years ago in year 1
- All courses show students learn what we intended
- Courses 1 & 3 have been renewed twice
- Only course 6 shows lower results in final iteration
- Choice in open practicals could be more diverse, but
- Became more diverse after inspirational matrices
- Minor adaptations necessary

Discussion

Year 2:

- Implementation has now reached year 2
- PE1 results were already high (98% → 100%)
- The combination of completely new courses and practicals proved difficult
- General idea seems very feasible
- Closed practicals need to be shortened
- Choice in open practicals could be more diverse
- Open practicals could be focused more on theory

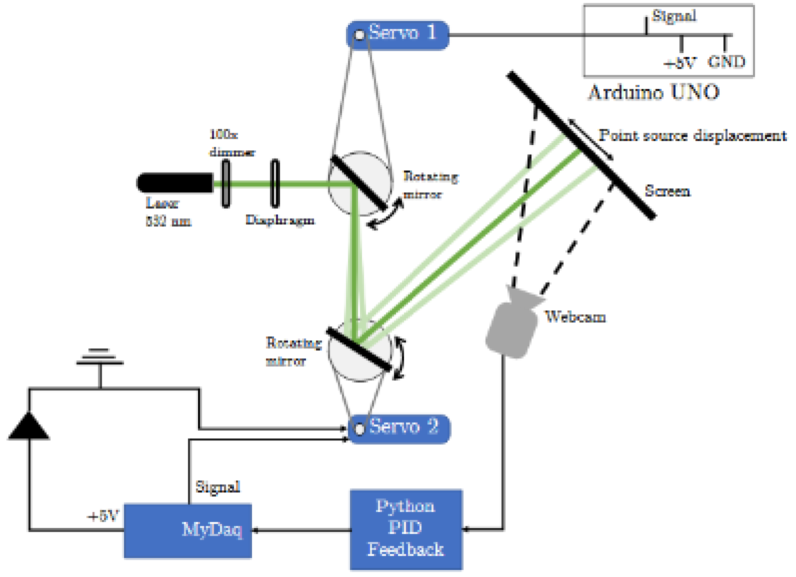


Figure 1:
The entire setup for our adaptive optics system. Servo 1 is the distortion source that rotates the mirror using a cord. Servo 2 is the motor correcting for the distortion.

Conclusion – design principles

There should be a need for the student to learn what we want them to learn (…)

- Need for preparation can be present by limited time to perform experiments in closed SQI practicals
- Need for lab journal may be present by repetition effect in closed SQI practicals
- Need for apparatus, analytical and programming skills present in closed SQI practicals
- Closed SQI practicals to prepare for open ISLE practicals
- Need for physics knowledge in practicals but not for students

New design!

- Need for research skills in open ISLE practicals
- Open ISLE practicals create a need to present or report based on lab journal
- Open ISLE practicals not always very diverse → inspirational matrices are a qay to go!
- Open ISLE practicals could be focused more on physics knowledge expansion

Conclusion

Learning objectives developed from bottom up can be connected to Dublin descriptors.

Learning objectives can be used to tell which Dublin descriptors they cover.

Attention to institute departments during implementation makes the courses locally relevant.

The newly designed course

- Is more challenging
- Has more built-in cohesion with other courses
- Has built-in connection to research departments
- Gives better or similar success rate

New course!

Future: development of rubrics based on learning objectives, improving inspirational matrices, digital lab journals

Questions or tips?

Paul Logman (logman@physics.leidenuniv.nl)

Universiteit Leiden
The Netherlands

Leiden Institute of Physics