

Exploring Changes in Students’ Understanding the Basic Concepts of Data Analysis in Introductory Laboratory Course “Search for Physics Laws”



Oksana Lozovenko¹, Dominik Giel²

Offenburg University of Applied Sciences, Germany¹
National University “Zaporizhzhia Polytechnic”, Ukraine¹
Offenburg University of Applied Sciences, Germany²

Common view on an introductory physics laboratory course

Good
Equipment

+

Well-written
Instructions

?

Enough Time

‘hope for self-dependent learning’ principle



‘systematic construction of skills’ principle

The main meaningful lines



Yevgeny Sokolov

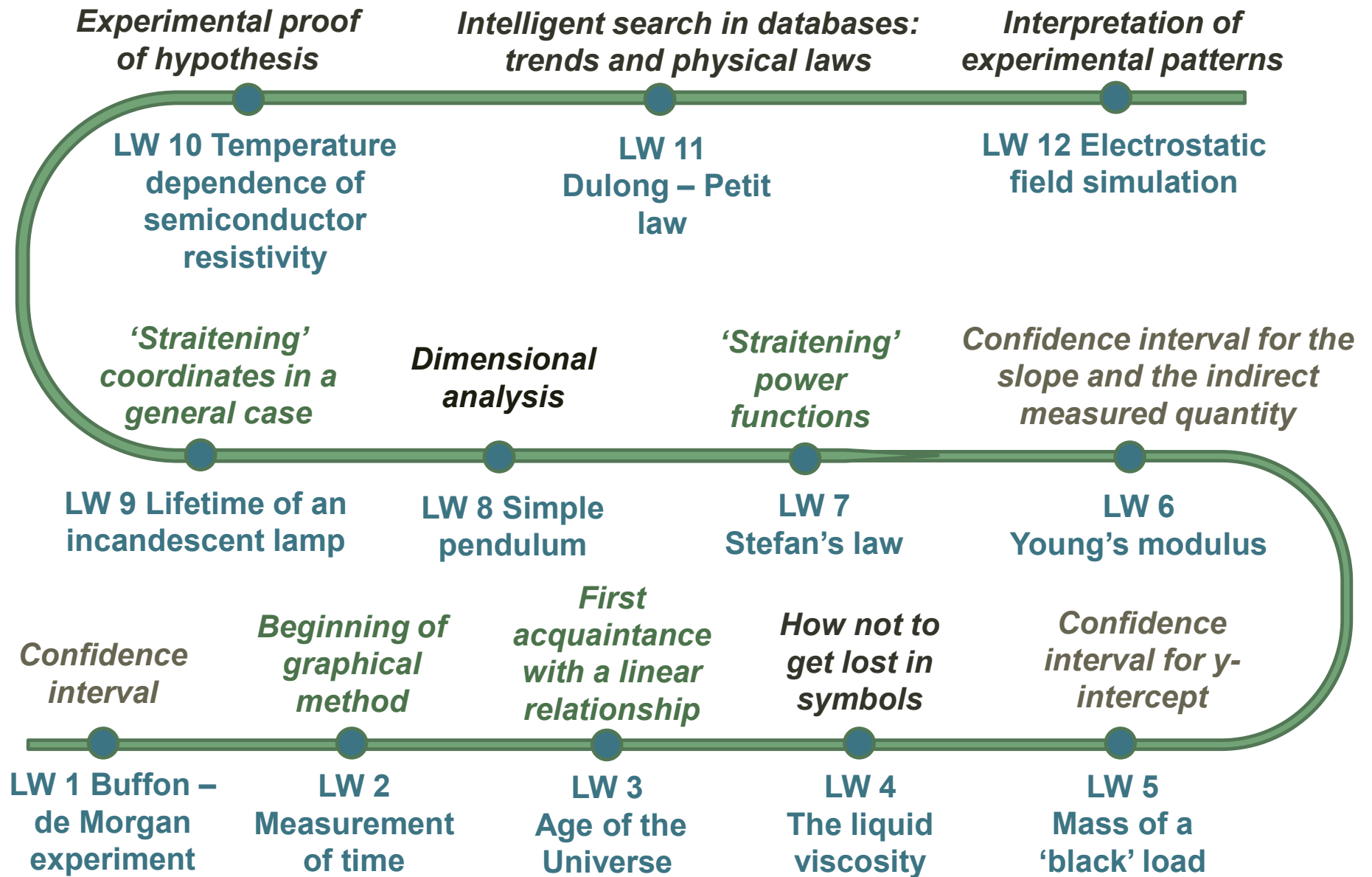
*from mechanics to thermodynamics
and electrodynamics*

*the graphical method of data analysis:
from linear dependences to trends*

*different types of experimental uncertainties:
slowly, step by step*

*general methods of research:
dimensional analysis, extrapolation, interpolation, modelling,
and testing a hypothesis.*





The main questions of the research

- **stability of students' results in the course over time**
- **the most challenging for first-year students basic concepts and procedures**

Stability of students' results in the course over time

Participants and data collection

2017 – 85 students in the experimental group, 61 students in the control group, positive results (see [6])

2018 – 74 students in the experimental group

2019 – 62 students in the experimental group

All students were first-year undergraduates followed 4 year BSc programmes in Engineering at the National University “Zaporizhzhia Polytechnic”

Questionnaire

1. (2 points) A student obtained an interval for coordinates of an object at the same instant: from 24.3 cm to 24.9 cm. Rewrite this result in the form $\bar{x} \pm \Delta x$.
2. (1 point) Find the fractional uncertainty in the following experimental result:
 64 ± 16 (μC).
3. (1 point) Find the absolute uncertainty in the following experimental result:
 $15 \text{ cm} \pm 20\%$.
4. (2 points) Round the following experimental result: height = 1.6432 ± 0.237 (m).
5. (2 points) A student measured some quantity three times, and obtained the following values: $x_1=24$, $x_2=24$, $x_3=21$. Write down the experimental result in the form $\bar{x} \pm \Delta x$.

Hint for #5:

$$\Delta x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n(n-1)}}$$

Students' results

Table 1. Students' results of questionnaire

Groups	Number of students who obtained scores		
	from 0 to 2	from 3 to 5	from 6 to 8
Control group - 2017 (after a traditional course, $N = 61$)	9 (15%)	38 (62%)	14 (23%)
Experimental group - 2017 (after the new course, $N = 85$)	9 (11%)	29 (34%)	47 (55%)
Experimental group - 2018 (after the new course, $N = 74$)	10 (14%)	24 (32%)	40 (54%)
Experimental group - 2019 (after the new course, $N = 62$)	6 (10%)	17 (27%)	39 (63%)

Data analysis

Groups

Control group - 2017
(after a traditional course, $N = 61$)

Experimental group - 2017
(after the new course, $N = 85$)

Experimental group - 2018
(after the new course, $N = 74$)

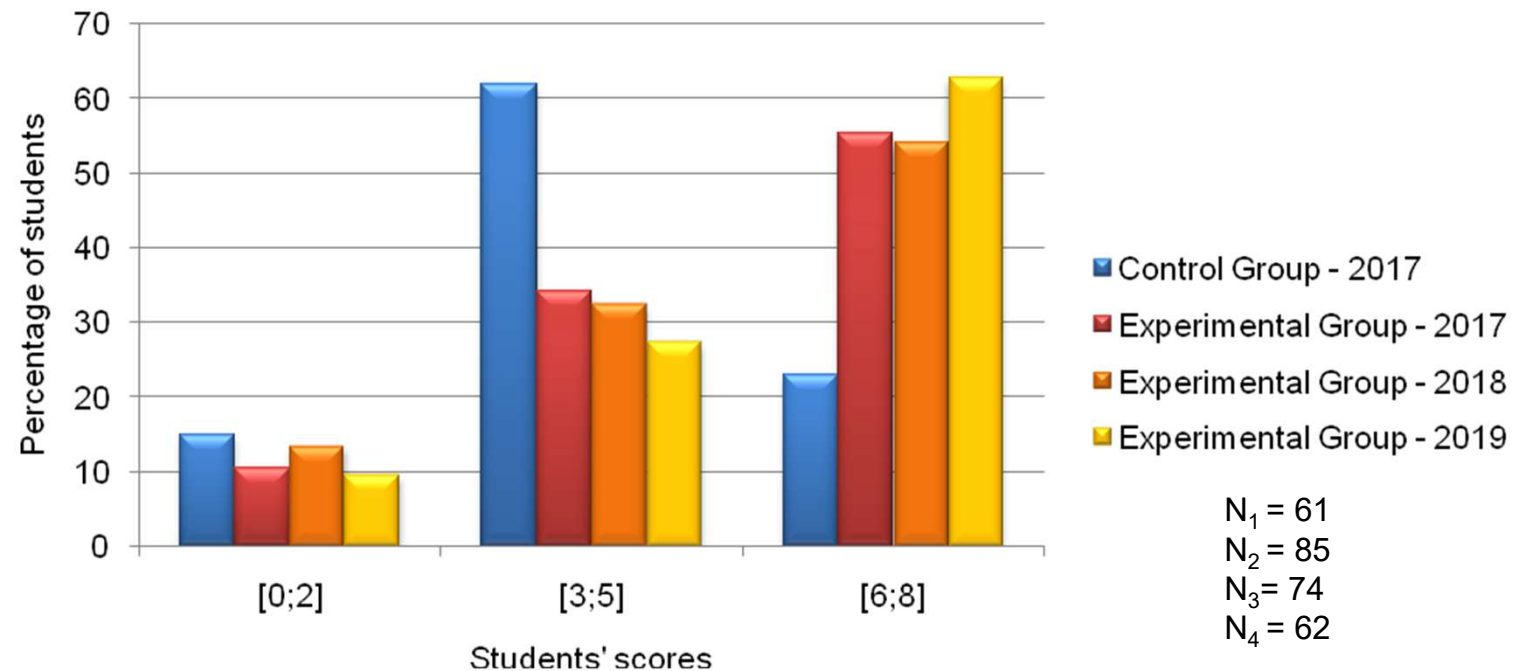
Experimental group - 2019
(after the new course, $N = 62$)

Chi-squared = 50.304, df 2, $p < 0.0001$,
Cramer's effect size = 0.42,

Chi-squared = 41.571, df 2, $p < 0.0001$,
Cramer's effect size = 0.39,

Chi-squared = 56.051, df 2, $p < 0.0001$,
Cramer's effect size = 0.48,

Stability of students' results in the course over time



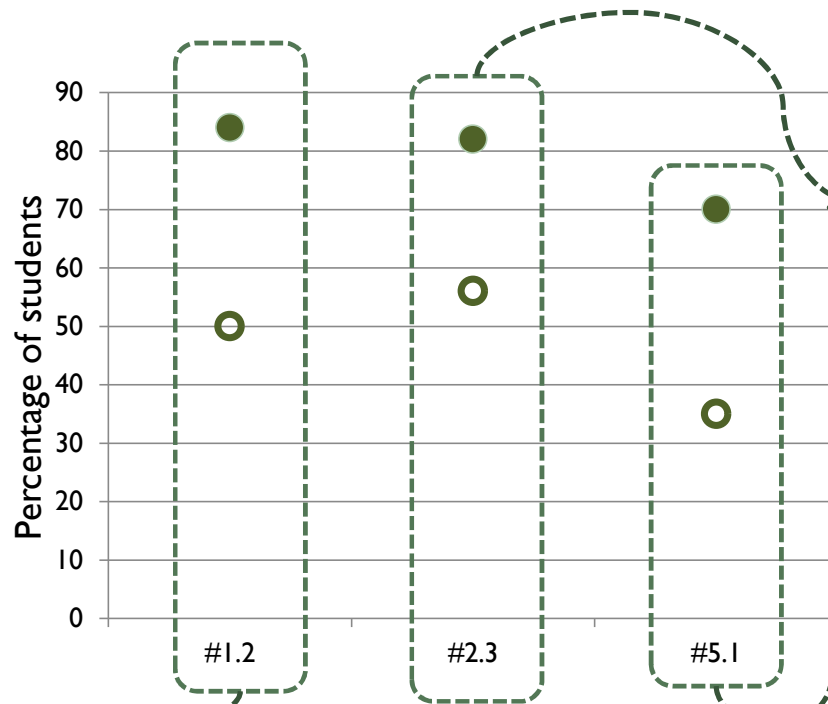
For each of the three experimental groups and the control group the differences are extremely statistically significant.

For each of the three experimental groups between each other the differences are not statistically significant.

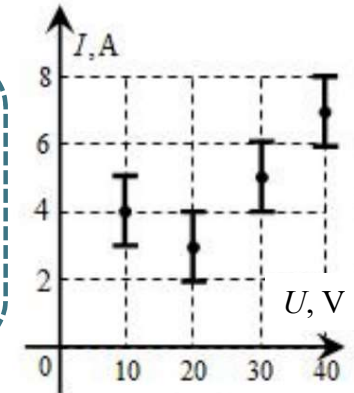
Students' understanding changes over the course

- results were obtained in 2021-2023 during online teaching
- the content of the course was not changed
- an instructor (via Zoom) discussed briefly with students the relevant background information
- students had to download their lab reports and also to pass a short quiz (3-5 items) about the corresponding method of data analysis
- at the end of the semester students (N = 76) passed the final quiz (13 items)

Questions with significant increase in the correct responses

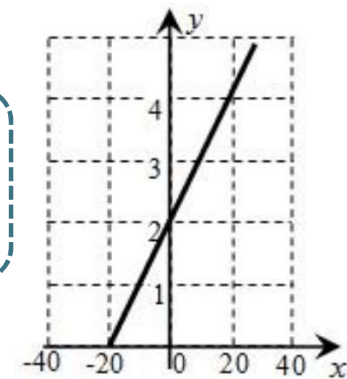


Determining the fractional uncertainty of the certain data point using the graph which shows an error bar through each data point.



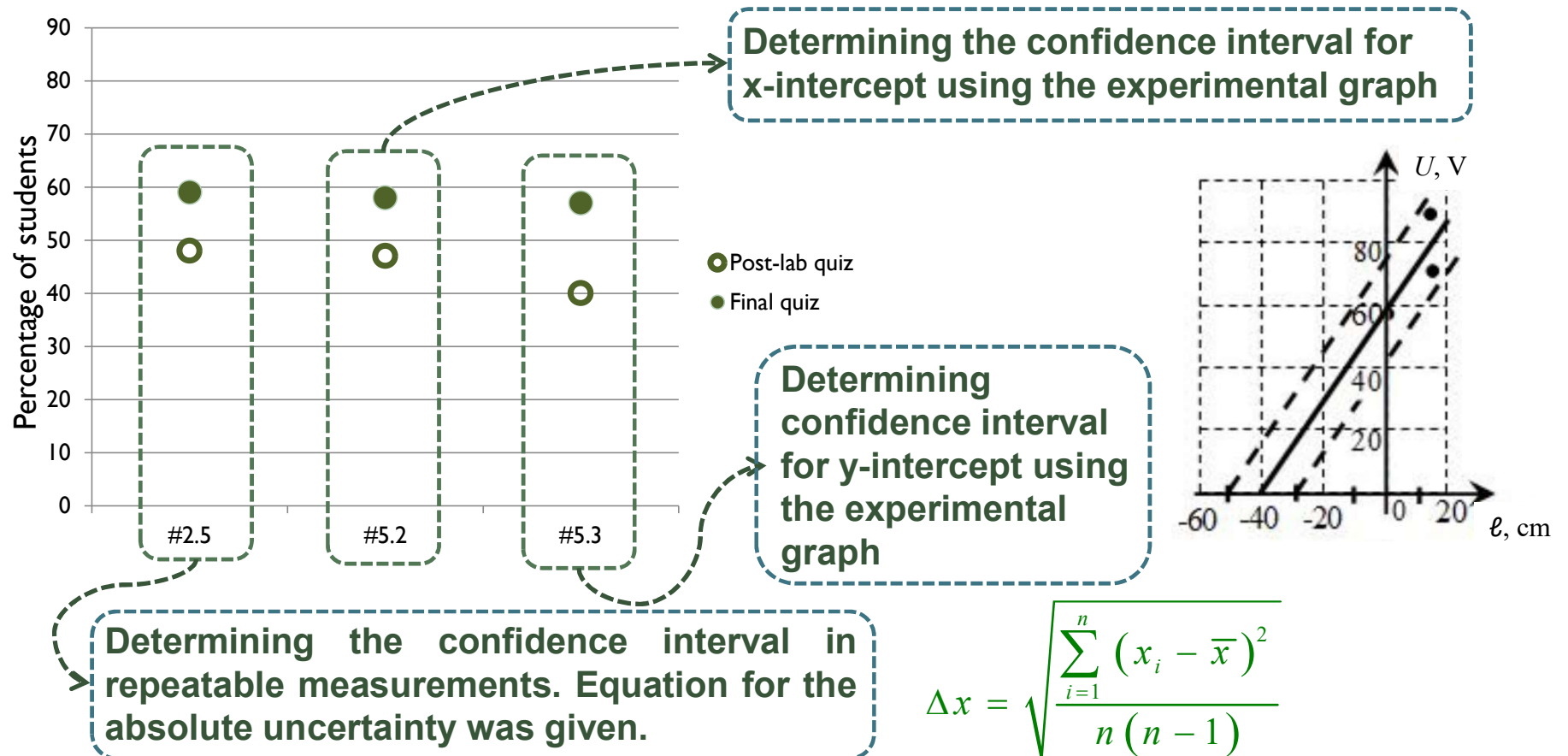
- Post-lab quiz
- Final quiz

Determining parameters b and x_0 in the equations $y = kx + b$ and $y = k(x + x_0)$ using a graph.



Rounding the experimental result:
height = 5.032 ± 0.04329 (m).

Questions with no significant increase in the correct responses



Conclusions

- We examined the effectiveness of the introductory laboratory course “Search for Physics Laws” with 221 students over three years and found a significant positive effect on students’ knowledge.
- We identified the most challenging for first-year students basic concepts and procedures.

These findings could be used by other researchers during developing laboratory, data analysis, and statistics courses.

Limitations

- one control group (2017, 61 students)
- students' understanding changes were registered for the whole group, not individually for each student
- only the 1st part of the course was evaluated

References

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- [6] Lozovenko, O., Sokolov, Y., Minaiev, Y. “Evaluation of students' understanding the uncertainties after a new course ‘Search for Physics Laws’”. International Journal of Engineering Pedagogy, 11(3), 2021, pp. 116–130.

The project on which this report is based was funded by the Federal Ministry of Education and Research of Germany (project ID: 57705968).

Thank you for attention !

Contact information:

Oksana Lozovenko

oksana.lozovenko@hs-offenburg.de