Teaching and Learning in Dialogue

Using discipline-based education research to improve student learning

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Active Learning in Engineering Education

- Goal
  - improve retention of engineering students
- Background
  - earlier studies suggest retention is affected by quality of instruction
- Focus
  - active learning in introductory engineering courses
    - Mechanics
    - Thermodynamics
    - DC and AC Electric Circuits
- Approach
  - investigate student understanding of fundamental concepts
  - use results to guide the development of instructional materials and improve instruction

NORDMETALL Stiftung

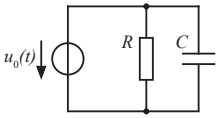
The limitations of traditional lectures

Example 1: Quiz question on AC phases

Lecture quiz

For the circuit shown, does a phase shift occur between …?

- $v_R(t)$ and $v_0(t)$
- $v_C(t)$ and $v_0(t)$



Correct responses

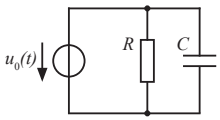
Both *R* and *C* are connected directly across the source, $v_R(t)$ and $v_C(t)$ are both identical to the source voltage $v_0(t)$ and therefore also in phase with it.

Example 1: Results from quiz question

Lecture quiz

For the circuit shown, does a phase shift occur between …?

- $v_R(t)$ and $v_0(t)$
- $v_C(t)$ and $v_0(t)$



Student responses

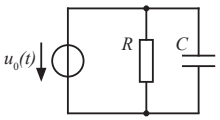
Percentage of correct answers	HAW EE Lecture (N = 49)	TUHH IT Lecture (N = 28)	TUHH ME Lecture (N = 268)	UW Physics CircuitsLab (N = 55)	
$\boldsymbol{v_R(t)}$ and $\boldsymbol{v_0(t)}$	*86%*	*100%*	*87%*	*87%*	
$\boldsymbol{v_C(t)}$ and $\boldsymbol{v_0(t)}$	*43%*	*32%*	*34%*	*49%*	

Example 1: Student reasoning

Lecture quiz

For the circuit shown, does a phase shift occur between …?

- $v_R(t)$ and $v_0(t)$
- $v_C(t)$ and $v_0(t)$



Student reasoning

- for $v_R(t)$: *"R* is ohmic load" or "*R* is purely real"
- for $v_C(t)$: "Phase shift due to capacitor" or "…due to charging of *C*"

Incorrect belief** that characteristic phase relationship of circuit element is relative to source voltage or current **is stronger than understanding of voltages in parallel

The limitations of traditional lectures

- Traditional lectures, when done well, may serve to
  - get students interested in subject matter
  - provide an outline of what is relevant in the field
- They are usually not sufficient for learning to occur, i.e. for the development of a functional understanding of core concepts.
- For similar student populations, the presence of conceptual difficulties is often fairly independent of the details of the instruction, e.g.,
  - the number of weekly contact hours,
  - the experience of the lecturer,
  - whether it includes standard laboratory experiments

Activating students in large lectures

- *Clicker questions ("Peer Instruction")*
- *Web-based pretests ("Just-in-time Teaching")*
- *Collaborative group work ("Interactive Tutorial Lecture")*

Clicker questions (Peer Instruction)

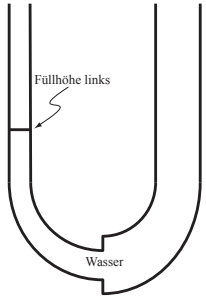
Example 2

Clicker question in hydrostatics

A U-tube with legs of different diameter (e.g. 1.5 and 3 cm) is partially filled with water. The water level on the left is as shown in the diagram.

The water level in the wider tube on the right …

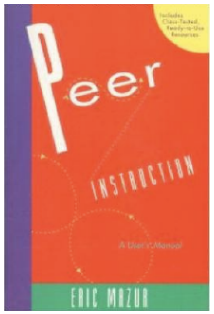
1. … is higher than on the left
2. … is lower than on the left
3. … is the same as on the left
4. … cannot be determined based on the information given



M. Loverude, P. Heron und C. Kautz, *Identifying and addressing student difficulties with hydrostatic pressure.* Am. J. Phys. 78, 75-85 (2010).

Peer Instruction (by Eric Mazur, Harvard)

- Use of electronic devices (clickers) to allow students to
  - individually and anonymously answer questions in lecture
  - discuss questions with their neighbors
  - vote on questions again
  - follow a brief class discussion on the possible answers
- Effective peer and class discussions require meaningful questions.



Example 2

Results in comparison with written test results

Water level on right	Thermodynamics I Summer 2006 *N* = 158	Thermodynamics I Summer 2007 *N* = 178	Engin. Mechanics Summer 2000 *N* = 168
… is higher	1%	3%	1%
… is lower	25%	21%	24%
… is equal	**73%**	**72%**	**75%**
… cannot be determined	1%	2%	0%

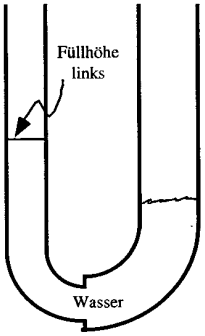
Conclusion 1: *Clicker questions yield valid results.*

Conclusion 2: *Predominant incorrect choice indicates basic misconception.*

Clicker questions can be validated through written tests

Horizontaler Querschnitt im rechten Schenkel ist $1{,}5^2 = 2{,}25$ mal so groß wie im linken Schenkel.

Da im Gleichgewicht die Wassermasse -> das Wasservolumen gleich sind, liegt die Oberfläche rechts entsprechend niedriger!



Horizontal cross section on the right is 1.52 = 2.25 times larger than that on the left.

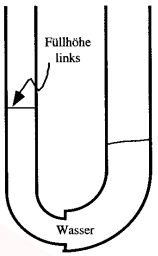
Since in equilibrium the mass of the water -> the volume of the water is equal, the surface on the right must be correspondingly lower.

Clicker questions can be validated through written tests

$$\rho A_e \cdot h_e \cdot \rho_w = A_R \cdot h_r \cdot \rho_w \rho, \quad A_R = 1{,}5\, A_l$$

$$A_e \cdot h_e = \frac{3}{2} A_e \cdot h_r$$

$$h_r = \frac{2}{3} h_e$$



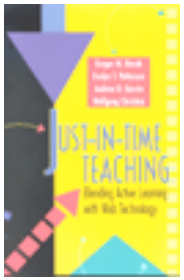
Some students mistakenly assume that hydrostatic equilibrium implies equal amounts (by volume or mass) of water on both sides.

Clicker questions can help us detect previously identified conceptual difficulties in a given student cohort.

Reading assignments and web-based pretests (Just-in-Time Teaching)

Just-in-Time-Teaching (by Novak et al.)

- What is JiTT?
  - Giving reading assignments before each lecture
  - Posing questions and problems for students to complete before lecture
  - Using student responses to questions to adjust content of lecture
- Goals of JiTT
  - Making better use of student-instructor contact hours
  - Encourage student to manage their own learning
- Tools of JiTT
  - Electronic media can be effectively used for this



Learning technologies should be designed to increase, and not to reduce, the amount of personal contact between students and faculty on intellectual issues.
(Study Group on the Conditions of Excellence in American Higher Education, 1984)

Implementing *Just-in-Time-Teaching (JiTT)*

Monday

Sunday, 11:30 pm

7:00 am

7:30 am

8:00 am

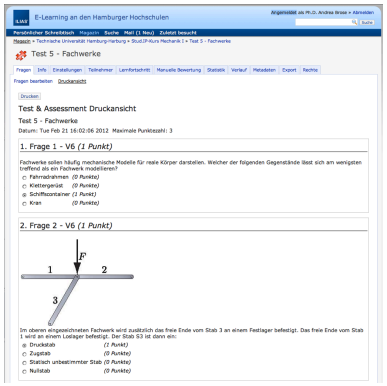
Images from www.presentermedia.com

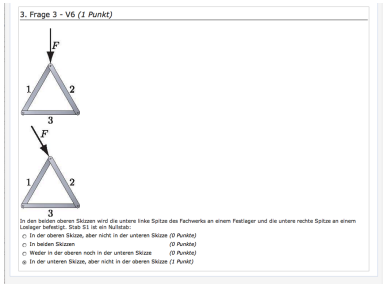
Implementing Just-in-Time Teaching *Mechanics I*

1. Reading assignment

Implementing Just-in-Time Teaching *Mechanics I*

2. Pretest





Benutzername	Testergebnis	Frage 1 - V6	Frage 2 - V6	Frage 3 - V6
studip_sara1419	3	1	1	1
studip_sama1452	2	1	0	1
studip_sosa2317	1	1	0	0
studip_sbra2156	3	1	1	1

Implementing Just-in-Time Teaching

- Small amounts of credit must be given for participation
- Very high participation (between 70 and 90% of about 700)
- Students seem very attentive in lecture when questions are discussed
- Students report usefulness of reading assignments and pretests
- Results from diagnostic test show increased learning gains

Collaborative group work (Interactive tutorial lectures)

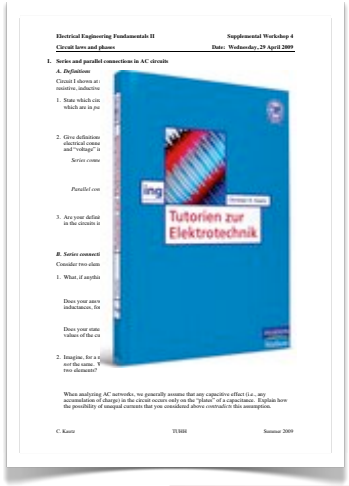
Interactive tutorial lectures

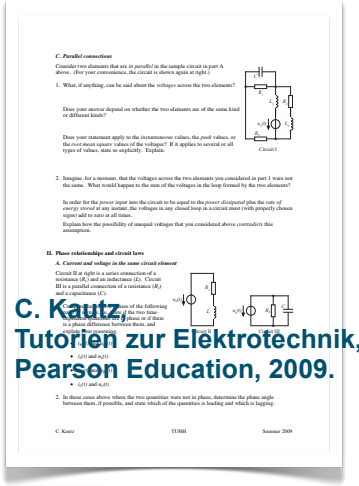
- *Goals of materials*
  - Help students overcome common difficulties
  - Strengthen understanding of important concepts and relationships
- *Approach*
  - Students work in groups of 3 or 4 through carefully structured worksheets containing mostly conceptual questions.
  - Guiding questions help students recognize the importance of relevant concepts and the motivation for mathematical tools.
- *Implementation*
  - Currently used in *Fundamentals of Electrical Engineering* courses
    - in small-group sections of 20 to 30 students, or
    - in large lecture sections of 100 to 400 students

    at various times throughout the semester
  - *Seminar on Engineering Education* is used for preparation of teaching assistants

Development of instructional materials

Tutorials for DC and AC electric circuit analysis





C. Kautz,
Tutorien zur Elektrotechnik,
Pearson Education, 2009.

Example 1: Results from quiz question

Lecture quiz

For the circuit shown, does a phase shift occur between …?

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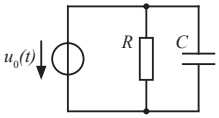
- $v_C(t)$ and $v_0(t)$



Student responses

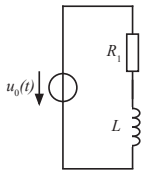
Percentage of correct answers	HAW EE Lecture (N = 49)	TUHH IT Lecture (N = 28)	TUHH ME Lecture (N = 268)	UW Physics CircuitsLab (N = 55)	TUHH EE Special (N = 90)
$v_R(t)$ and $v_0(t)$	*86%*	*100%*	*87%*	*87%*	*92%*
$v_C(t)$ and $v_0(t)$	*43%*	*32%*	*34%*	*49%*	*59%*

Development of instructional materials

Tutorial on circuit laws and phases in AC circuits

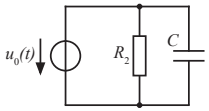
(Excerpt) Students are asked to consider a hypothetical student dialogue and to explain the flaws in the reasoning displayed.

Michael: *"In an inductance, a voltage is induced that opposes any change in current. Therefore the current gets delayed after it passes through R1 when it reaches L. There must be a 90° phase difference between the current through L and that through R1."*



Circuit II

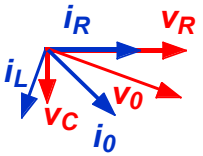
Ben: *"I was wondering about the voltages in Circuit III. For a capacitor, charge must first accumulate on the plates before the voltage reaches its peak value. This means that the voltage across C experiences a 90° phase shift relative to the voltage across R2."*

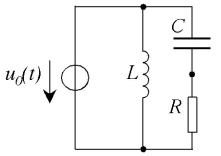


Circuit III

Example 3: Assessment of learning gains

Results
(after modified instruction: *Interactive Lecture*)

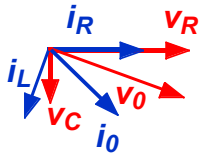


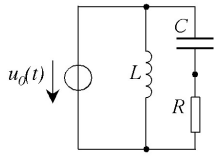


Percentage of correct answers	2007 ME + EE Lectures (N = 196)	2009 Mech. Eng. Tutorial lecture (N = 435)
a) $v_L(t)$ and $v_0(t)$	47%	76%
b) $i_C(t)$ and $i_R(t)$	56%	75%
c) $v_R(t)$ and $v_0(t)$	38%	67%
d) $i_0(t)$ and $v_0(t)$	–	(34%)

Example 3: Assessment of learning gains

Results
(after modified instruction: *Active-Learning Tutorials*)





Percentage of correct answers	2007 ME + EE Lectures (N = 196)	2009 Mech. Eng. Tutorial lecture (N = 435)	2010 Electr. Eng Group tutorials (N = 102)
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c) $v_R(t)$ and $v_0(t)$	38%	67%	59%
d) $i_0(t)$ and $v_0(t)$	–	(34%)	75%

Conclusions

- Traditional lectures are often not sufficient for students to develop a functional understanding of core concepts.
- For similar student populations, the presence of conceptual difficulties is often fairly independent of details of instruction.
- Methods that can help to increase student learning in large lectures include
  - Peer Instruction
  - Just-in-time teaching
  - Interactive tutorial lectures
- Student activation has a greater chance of being successful if it takes into account previously identified student difficulties
- Discipline-based education research can contribute to the improvement of student learning even in large lectures.