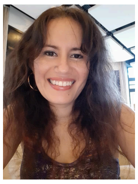
Transforming student and staff experiences with active learning tutorials in advanced chemistry courses



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ViCEPhEC2020

Learning science by doing as real-world scientists do

Creativity

Expert thinking

Student's interests, motivations

Student's self-confidence

Why?

How scientists do science

Understand and solve complex problems effectively

Work collaboratively to identify the right questions

Apply creativity to formulate theories, test new experiments

Learning science should not depart from experiencing the exiting process of doing science

How?

Taking active learning a step further

Active learning has been centred on academic results…


PNAS

Active learning increases student performance in science, engineering, and mathematics

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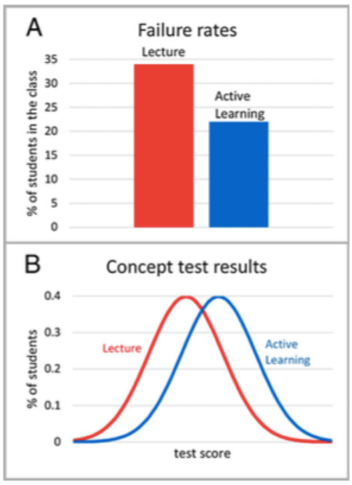
To test the hypothesis that lecturing maximizes learning and … 225 studies in the published and unpublished literature. The active

We are integrating to this the development of the

- Students' **self-confidence**
- the **stimulus of their creativity and interests**



Wieman, PNAS, 2014

Active learning tutorials: the design

Pre-tutorial Activities

- Individual work
- Revision

Focused on Content

Tutorial session

Small-group Discussions and Collaboration

- Learning Goals
- Peer learning/feedback
- Gaining self-confidence
- Context-rich/real-world problems

Whole class discussions and presentations

- Communication skills
- Evaluating/Defending ideas

Focused on creativity and self-confidence

The courses

Course	Topics	Students
Advanced Topics in Physical Chemistry	Electrochemistry Surfaces and Soft Matter.	140 students: 120 BSc in Chemistry (YEAR 3) 20 BSc/MSci Natural Sciences.
Advanced Topics in Inorganic Chemistry	Organometallic compounds Band Theory	128 students: 119 BSc in Chemistry (YEAR 3) 7 BSc Natural Sciences 2 MSci in Chemistry
Advanced Topics in Organic Chemistry	Stereocontrolled synthesis Cyclic/polycyclic molecules	180 students: 120 BSc in Chemistry (YEAR 3) 60 BSc/MSci Natural Sciences.

Course teaching structure

AUTUMN TERM

SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER

32 lectures

SPRING TERM

JANUARY | FEBRUARY | MARCH | APRIL

3 Tutorials

Example of tutorial schedule (9 student groups): 1 hour-tutorial per course each three weeks

CHEM0030 Advanced Inorganic Chemistry	10 am	11 am	1 pm
Week 1	Group 1	Group 2	Group 3
Week 2	Group 4	Group 5	Group 6
Week 3	Group 7	Group 8	Group 9

Transforming standard tutorials with active learning

Advanced Topics in Physical Chemistry

➢ **Tutorial: Electron Transfer (electrochemistry)**

Learning Goal: The idea of this tutorial is to get you **thinking** as an **examiner** setting a problem for a final exam

Student-generated content

Example of

Small-group Discussions and Collaboration

Task overview: In your group you will now prepare a short question (equivalent to approx. 5 marks of a typical exam question) on the subject of Tafel Analysis, or Butler-Volmer kinetics more broadly if you like. You will also prepare a model answer.

In your group you should:

1. Decide what the aim of your question is – do you want to test KNOWLEDGE, APPLICATION or UNDERSTANDING? (You can address more than one if you want).
2. Write the question and a model answer. Consider carefully how to phrase the question so that it tests what you want and so there is no confusion. Make sure you provide all the information necessary to answer the question.
3. Write a short (1-2 sentence) description of the reasoning/motivation behind the question and which of the learning objectives you were testing.

Scaffolded/guided activity

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Advanced Topics in Inorganic Chemistry

➢ **Tutorial: Organometallic Chemistry**

Learning Goal: The idea of this tutorial is to get you **thinking** like an **industrial researcher.**

Example of

Small-group Discussions and Collaboration

1. Design Phase

You are research group at a chemical company that sells various organic compounds. You have been tasked with designing an organometallic catalyst of an organic reaction such as metathesis, coupling, C–H activation, polymerisation etc. In your groups discuss the following:

- What are the characteristics of a good organometallic catalyst?
- Your choice of metal, its d-electron count and its oxidation state.
- Your choice of ligands and how th
- How you think the catalyst might synthesis might be scaled up.
- The stability of the catalyst and its
- The ease with which the catalyst a

Scaffolded/guided activity

2. New Research Phase

The company director has asked your group to work towards a solution of another major application of an organometallic catalyst. Choose one of the following applications (or come up with your own) and discuss how you would go about designing an ideal organometallic complex for that application.

- Design of a catalyst for a different organic reaction to that in part 1.
- Design of a precursor to a thin-film material for chemical vapour deposition or atomic layer deposition.
- Design of a complex for photovoltaic applications.
- Design of an organometallic complex for a biomedical application, such as a chemotherapy drug.

Connection to a real-word problem

Opportunity for creativity

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Advanced Topics in Organic Chemistry

➢ **Tutorial: Aminosugar Synthesis**

Learning Goal: The idea of this tutorial is to get you **thinking** as a **real-world chemist**

Example of

Small-group Discussions and Collaboration

Context-rich problem

Group Activity: You are a small group of chemists working in a medicinal chemistry company on the development of novel anti-HIV drugs. As part of this project, you are tasked with the synthesis a library of aminosugars from D-glucose including examples where the amino group is incorporated at each position of the sugar (i.e. C-1 right through to C-6; only one amino group in each compound).

Scaffolded activity

1. [20 min]: Working in groups of ~3-4 people, discuss the strategies you have identified in your pre-tutorial work for selectively protecting sugars. Selecting one of those strategies, devise a route to prepare an amino sugar from glucose. Include full details (reagents/conditions) of all reactions and a justification of the expected selectivity. Try also to identify any potential pitfalls with the synthesis – i.e. What might go wrong?

What?

Evidence of reaching LEARNING GOALS

- **Students writing an exam question from scratch: doing as an examiner**
  - *Students submitted a good level of exam questions. This was reflected in the instructor feedback being able to slightly modified versions of most of the questions as revision aids on Moodle.*

> *"The discussion about their exam questions has turned out to be a good way of getting them to think about their understanding of the topic and how many different points would need to be included in the answer and hence how many marks it is worth."* Advanced Topics in Physical Chemistry module's Instructor

- **Students designing ideas for an industrial application: doing as an industrial researcher**
  - *Students actively looked up academic papers on their devices and discussed interesting ideas for their designs.*

- **Students proposing solutions for a context-rich problem: doing as a chemist**
  - Students discussed possible strategies for the synthesis of an aminosugar and critically assessed their solutions
  - Each group handed in a copy of their proposed synthetic route to an amino sugar and the class collectively discussed potential problems with their choice and order of reactions, coming up with solutions.

Evidence of increased ENGAGEMENT

Students attendance to active learning tutorials > 80 % of total class

Students' submissions: 100% of the class submitted the tutorial activities by end the sessions

With previous standard tutorials: ~ 50% student attendance

What students have to say

1. What aspects of the tutorials did you find the most useful and why?

It was useful to discuss in groups and see different perspectives of approaching questions.

Pre-tutorial work was useful in terms of preparing for participation.

Having us work through the problems ourselves in groups is great. That way we actually have learn to think about them.

Discussing/working in small groups

– Working in groups as it allows us to bring together different ideas and the thought processes behind those ideas.

"Students love working in groups - this to me was the most powerful aspect of this. The fact that they recognised how well they learnt from doing this and articulated it so well in these surveys is so great!" Tutorial instructor.

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What students have to say

→ The exam style questions are great. These questions give me a general idea about the content that I must understand.

Writing exam questions helped them to a deeper understanding

Physical tutorial was useful – got to try exam style question and think how we would be examined.

Design questions helps me understand the concept deeper.

"I am very surprised at the broad range of topics they are picking to write exam questions on. Hardly any of them are going for the 'easy' option of one of my hints / suggestions." Tutorial instructor

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What students have to say

- Being in groups + working together
- Application of knowledge & more research-oriented situations

Opportunities for creativity and to explore research-oriented questions

Rather than answering questions, it was interesting to discuss the applications and come up with creative ways (for example inorganic chem.) which might benefit in my further studies into chemistry

I think this style of tutorial has been really beneficial unlike previous years where students were forced to go up to the board and answer since I wasn't able to understand the content

What instructors have to say

- **Contribution to staff own motivation:**

"There was a real buzz in the room most of the time and I could hear students genuinely discussing the chemistry and suggesting ideas."

"It was brilliant for me - much more enjoyable to teach, and I was definitely excited afterwards. I am actually looking forward to next week."

"For the last couple of years I've usually felt tired, drained and bit depressed after 3 tutorials - but this year I feel way less tired and much more positive about the students learning. I feel like now *they* are doing the work. Last year I definitely felt like I did the work on their behalf when I just told them the answer and worked really hard to drag answers out of them. I prefer teaching this way so would continue to do it! It's more relaxing and less draining."

- **Creating a relaxing learning and teaching environment:**

"The really nice thing was listening to students who obviously didn't know each other well having a chat about where they came from and their families while they were working. It was super nice and didn't interrupt their work or how engaged they were (much!) and this wouldn't have been possible in the old setting where they just sit and listen to me."

- **Staff own learning gains**

"Students were actually looking up academic papers on their devices as part of their discussion! As a result, I learnt a few new things myself."

"The students did really well. They came up with a wide variety of answers, some of which I hadn't thought of!"

- **Effective use of staff time:**

"From my perspective, going round the groups was like a mini tutorial, so it gives the effect of very small group learning while the group is still large: I now have more time to address individual concerns, work out where calculations went wrong etc - I think they get more one to one attention. "

In summary

- Students increased motivation, engagement and performance.
- Students felt the active learning tutorials supported their learning and valued the opportunity to apply knowledge to practical situations
- Staff experienced a transformative teaching/learning situation: using the tutorial design supported them to make a more efficient use of the tutorial time.

And then what?

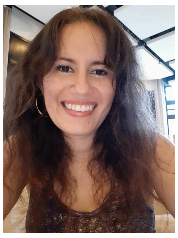
Chemistry Education Innovation and Research

During the second implementation we plan to:

- Measure learning gains, self-efficacy and self-directed learning.
- Expand the active learning tutorial design to more sessions and promote adoption other courses

Physics & Chemistry education collaboration

The team



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Thank you for listening!