Martin Cramer Pedersen

Teaching Portfolio

Teaching and organization

2022 **Organizer of and lecturer at the Ph.D. school *Geometry and topology in contemporary materials science III***
Niels Bohr Institute, University of Copenhagen

2020-2022 **Lecturer at several smaller courses on scattering physics and related data science at M.Sc. and Ph.D.-level**
Niels Bohr Institute, University of Copenhagen

2019–2020 **Organizer of and lecturer at the 1st year course *MatN: Linear algebra***
Niels Bohr Institute, University of Copenhagen

2017 **Co-organizer of and lecturer at the Ph.D. school *Geometry and topology in contemporary materials science II***
Niels Bohr Institute, University of Copenhagen

2015 **Lecturer in the 4th year course *Neutron scattering***
Niels Bohr Institute, University of Copenhagen

2013–2014 **Course instructor in the 4th year course *Neutron scattering***
Niels Bohr Institute, University of Copenhagen

2012 **Course instructor in the 3rd year course *Physics for biotechnologists***
Niels Bohr Institute, University of Copenhagen

2011–2012 **Course instructor in the 1st year course *Mathematics and computing***
Department of Mathematical Sciences, University of Copenhagen

Education and accreditation

2020 **Supervision of PhD Students**
30 hour course, Department of Science Education, University of Copenhagen

2020 **Supervision of BSc and MSc students**
30 hour course, Department of Science Education, University of Copenhagen

2019–2020 **Teaching and Learning in Higher Education Programme (Universitetspædagogikum)**
175 hour course, Department of Science Education, University of Copenhagen

2019 **Introduction to University Pedagogics**
77 hour course, Department of Science Education, University of Copenhagen

2016 **Associate fellow of the Higher Education Academy (AFHEA)**
Educational Fellowship Scheme, Australian National University

Student supervision

2022 **Indep. project, Unique Gyanu Yogi,** Supervisor w/ Jacob Kirkensgaard
2022– **Industr. Ph.D., Zsófia Edit Szathmáry** Co-supervisor w/ Jacob Kirkensgaard
2021–2022 **M.Phil. (ANU), Yanzhi Guo,** Co-supervisor w/ Vanessa Robins and Jacob Kirkensgaard
2020– **Ph.D., Abigail Barclay,** Co-supervisor w/ Lise Arleth and Kresten Lindorff-Larsen
2020–2022 **M.Sc., Jakob Kruse,** Co-supervisor w/ Lise Arleth and Abigail Barclay
2020–2021 **M.Sc., Sara Blemmer,** Supervisor w/ Lise Arleth, Nicolai Johansen, and Frederik Tidemand
2020 **B.Sc., Anders Dahl,** Supervisor w/ Jacob Kirkensgaard

2018–2019 **M.Sc., Abigail Barclay,** Co-supervisor w/ Lise Arleth and Nicolai Johansen

2015 **B.Sc., Viktor Holm,** Co-supervisor w/ Lise Arleth and Søren Midtgaard

2014 **B.Sc., Gertrud Dam-Dalgeir,** Co-supervisor w/ Lise Arleth and Søren Kynde

2013 **B.Sc., Andreas Larsen,** Co-supervisor w/ Lise Arleth, Jacob Kirkensgaard, and Søren Midtgaard

Statements

2022 **Excerpts from anonymous student evaluations of the Ph.D. school Geometry and topology in contemporary materials science III:**

- *"Excellent content delivered in an excellent way! All the lectures were well structured and relevant to my research in a great extent. Also the existence of project work was helpful to get in touch with the course material and practice it. Highly interactive, interdisciplinary and uniting the applied geometry world. Thanks!"*
- *"Very nice school, incredibly great teachers! Incredibly inspiring. Also high pace of course, which is expected, a lot of material and many hours, but I felt it was at a good level still."*
- *"It was a fantastic week, and I am really happy I was able to be a part of it. I learnt so much!"*

2020 **Excerpts from the final evaluation/Teaching Statement in the *Teaching and Learning in Higher Education Programme (Universitetspædagogikum)*-course**

- *"Attending his online lectures was an extremely pleasant experience, one that did not feel so different from a presential lecture, due to Martin's technical and pedagogical expertise, not to mention his flawless time management."*
- *"...it is clear that Martin invites open dialogue about his teaching and how it can be improved."*
- *"...we consider Assistant Professor Martin Cramer Pedersen to be an excellent teacher in higher education. He plans his teaching carefully and thoroughly."*

2020 **Excerpts from anonymous student evaluations of the *Linear algebra and classical mechanics (MatN)*-course:**

- *"Good lecturer, I think he was particularly good at adapting to the on-line format of the course."*
- *"Martin was really great at taking the time to listen to our questions and then answering them in a way that makes you understand whatever you were unsure of."*
- *"...wonderfully clear about expectations and intented learning outcomes".*

2019 **Excerpts from anonymous student evaluations of the *Linear algebra and classical mechanics (MatN)*-course:**

- *"Very enthusiastic and had always uploaded material and instructions beforehand. It was clear that he cared about our learning outcome and would always attempt to help in any way possible."*
- *"Really good lecturer, and great that he took the time to be present at the problem solving sessions, so you can discuss with him and understand the material in depth."*
- *"...very engaging, and the lessons were interesting and fun."*

2016 **Excerpts from the evaluation of the AFHEA application:**

- *"You clearly have a deep passion for mathematics and physics, and this shines through in your teaching. This interweaves with your passion for teaching, which is grounded in academic literature and acts as a basis for your continual evolution as an educator."*
- *"You are acutely cognizant of the wide range of different backgrounds, ability levels and interests within your student cohorts, and employ strategies to get the best out of every student."*
- *"You strongly demonstrate a commitment to reflective practice in thinking about how students learn, and how you can tailor your teaching to their needs. You demonstrate a deep sense of respect for students."*

Appendices - Reflections, projects, and applications

2020 **Didactic project on *Expanding student perception of linear algebra***

2020 **Reflection on the didactic congruence of the *Linear algebra and classical mechanics (MatN)*-course**

2019 **Reflection on Feedback to Students**

2019 **Reflection on Research-based Teaching**

2016 **Application for Associate Fellowship at the Higher Education Academy (AFHEA)**

Appendices - Evaluations, diplomas, and certificates

2020 **Diploma from the Supervision of BSc and MSc students course**
Department of Science Education, University of Copenhagen

2020 **Diploma from the Supervision of PhD Students course**
Department of Science Education, University of Copenhagen

2020 **Teaching Statement from the final evaluation in the Teaching and Learning in Higher Education Programme (Universitetspædagogikum) course**
Department of Science Education, University of Copenhagen

2020 **Diploma from the Teaching and Learning in Higher Education Programme (Universitetspædagogikum) course**
Department of Science Education, University of Copenhagen

2019 **Diploma from the Introduction to University Pedagogics course**
Department of Science Education, University of Copenhagen

2016 **Evaluation from the Higher Education Academy (AFHEA)**
Australian National University Educational Fellowship Scheme

2016 **Certificate from the Higher Education Academy (AFHEA)**
Australian National University Educational Fellowship Scheme

UP Final Project on

Expanding student perception of linear algebra

Martin Cramer Pedersen

Introduction

This report concerns itself with a project related to the course *Linear algebra and classical mechanics* [1] (referred to as *MatN* from this point). The course is a mandatory first year course for students in the nanoscience study programme at the University of Copenhagen located in the block four before the summer break; as shown in Figure 1.

	Blok 1	Blok 2	Blok 3	Blok 4
1. år	Nano 1 - introduktion til nanovidenskab	Introduktion til matematik for de kemiske fag	Sandsynligheds-regning, dataanalyse og indledende ellære	Elektromagnetisme og elektronik
	Organisk kemi i naturvidenskab		Almen og uorganisk kemi	Lineær algebra og klassisk mekanik
2. år	Nanotermodynamik	Nanokvant	Kvantefænomener i nanosystemer	Molekylær statistik
	Nanobio 1	Nanobio 2		
3. år			Nanobio 3	
			Bachelorprojekt	

Figure 1: The 2020 course plan for the B.Sc. programme in nanoscience at University of Copenhagen [2]. *MatN* is highlighted in light blue, whereas white and grey spaces are elective and restricted, elective courses, respectively.

The main purpose of the course is to supply the students with the tools and mathematical understanding needed for the subsequent courses in quantum mechanics and statistical physics in the second year of the study programme. The course consists of two separate parts: linear algebra and classical mechanics. This project concerns itself with the former.

A recurring problem in the course - or perhaps rather in the following courses relying on the skills and materials taught in this course - is the students' lack of ability to deploy the concepts taught in this course in the context of other courses and contexts. To use the SOLO taxonomy [3]: most students are not elevated from a unistructural understanding of the material to a multistructural understanding. This is problematic, as an abstract, multistructural understanding of certain central topics in linear algebra is a prerequisite for the subsequent courses in quantum mechanics.

Among other initiatives taken this year, the 2020 edition of the course featured a new teaching method: so-called reflection exercises. Simply put, the idea was to expose the students to problems of a more theoretical and abstract nature rather than the more calculation-intense and algorithmic problems usually found in first-year mathematics courses; in particular courses in linear algebra. Or perhaps rather problems demanding a more lateral and intuitive understanding and approach to the topics in linear algebra.

As a second motivation, the students generally struggle appreciating the objective relevance of the material, as it is presented to them. On several occasions, I have had students asking me: "*Why do we have to learn [matrix inversion/eigensystems/change-of-basis]?*" The relevance of the various mathematical topics in the course will definitely become evident for them during later courses, and I do attempt to expose them to illustrative examples of scientific applications of linear algebra. By stressing the importance of intuition in linear algebra, my hope was that the general applicability of the material, algorithms, and methodology covered in the course might be more appreciated by the students.

The 2020 edition of the course was taught entirely on-line due to the Covid-19 outbreak; which greatly influenced the course planning, teaching methods, and overall student experience; as well as the execution and expected results of the planned changes and their impact. For this project, it is particularly important to note that all classroom sessions were conducted using the on-line meeting tool Zoom [4].

Format and Intentions

The exercises were designed and structured around the TDS model [5] as described below:

1. Devolution: The exercises were introduced by a slide shown in class. An example of these slides is shown in Figure 2; the full set of exercise problems can be found in the Appendix.
2. Activation: The students were separated into groups of 3 to 5 using the break-out room function in Zoom.
3. Formulation: Each group prepared their arguments and formulated solutions to the presented problem in their respective break-out room.
4. Validation: These arguments and solutions were on a shared, public Padlet website [6]. Students were encouraged to read the other replies and consider their soundness and supporting argumentation. An example of a reply is shown in Figure 3.
5. Institutionalisation: After the exercise, the students were called back to the main Zoom classroom, and the various arguments and solutions were outlined, discussed, and assessed. As shown in Figure 4, this was done in an attempted mimicking of traditional "blackboard" teaching.

Each classroom session consisted of 2 subsessions of 45 minutes with a 15 minute break in-between (small 5 minute breaks were also held during the 45 minutes). The exercises were presented before the 15 minute break and the institutionalisation phase began 5 to 10 minutes after the break.

Usually, the students stayed in their group rooms for the entire duration of the extended break; though often not discussing the presented problem for the full 25 minutes.

The primary concerns and hopes when designing and formulating the exercises were i) not simply regurgitating traditional calculation-intense linear algebra assignments; the students were supposed to be trained in these during problem solving sessions after the class, ii) encouraging and training students in the habit of presenting solutions and mathematical arguments in concise and understandable writing, and iii) utilize elements from cooperative learning [7] in a class composed of students displaying a considerable span of skills and abilities in mathematics. Specifically, my hope was that the weaker students might benefit from discussion-style exercises in randomized groups.

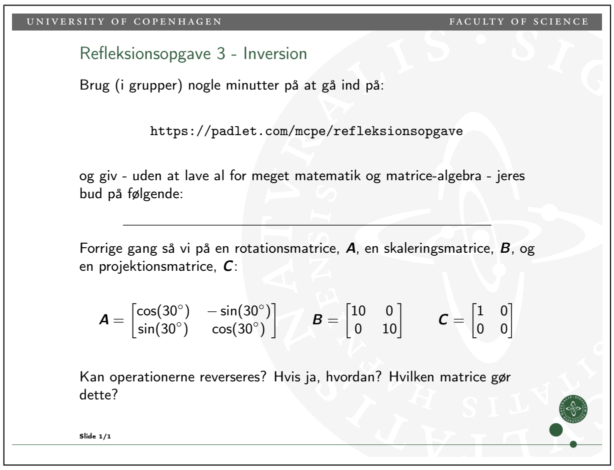


Figure 2: The third reflection exercise which focuses on the intuition behind matrix inversion. The students are asked to assess, whether or not the presented matrix operations, $\boldsymbol{A}$, $\boldsymbol{B}$, and $\boldsymbol{C}$ can be inverted. Preferably by using intuition rather than relying on calculations.

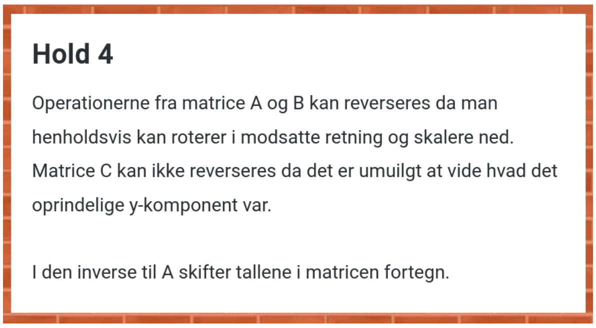


Figure 3: Screenshot of a student group reply from Padlet.

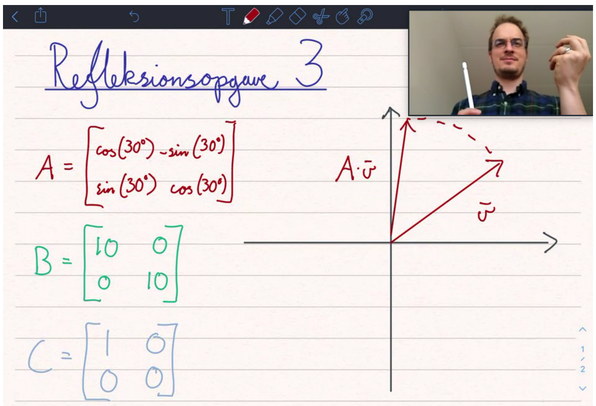


Figure 4: Screenshot of the institutionalisation part of the exercise - using Zoom, an iPad, and the app Notability.

Note that in some of the exercises, the students were explicitly asked not to do any computations in an attempt to solicit answers based on intuition. At times it felt necessary to emphasize this aspect of the exercise - as well as to remind the students of the intended learning outcomes.

Outcomes and Reception

At the end of the course, the students were asked to fill out an informal course evaluation via Socrative [8]; in which they were asked to express their opinions on the various teaching methods and tools applied during the different parts of the course. A total of 8 questions were posed to the 23 attending students.

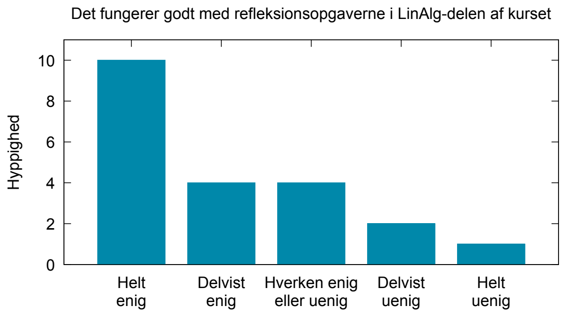


Figure 5: Student responses to *"The reflection exercises in linear algebra work well"* in the unofficial course evaluation. The responses range from *"completely agree"* (Left, in Danish: *"Helt enig"*) to *"completely disagree"* (Right, in Danish: *"Helt uenig"*).

The responses to the question about the reflection exercises are plotted in Figure 5; and as shown the polled students were generally appreciative of the teaching activity. *En passant*, it is worth noting that this survey is likely highly biased towards students with positive opinions of the classroom sessions and teaching activities.

The students were reasonably active during the reflection exercises, and most groups usually made quite an effort as evidenced by the amount and overall quality of the postings on the associated Padlet website. The subsequent institutionalisation sessions were definitely the parts of the lecture sessions with the most questions and student engagement.

From the teacher's perspective, the exercises offered good opportunity to gauge the students' proficiency in and understanding of some of the more subtle points in basic linear algebra. As the exercises were placed in the middle of a classroom session, they allowed for correcting apparent misunderstandings on the spot and for further elaboration on essential points relevant to the exercises. In the context of the flow of the lecture sessions, they offered convenient segues from a longer break to institutionalisation and onwards to the traditional lecture format and the day's material to be covered.

Furthermore, the exercises offer some interesting opportunities for some just-in-time learning [9]; i.e. one can design the exercise to emphasize exactly the point, theme, or algorithm needed for lecture session directly following the exercise. Or sometimes to highlight pitfalls in previously covered material. Again, this also adds to the flow of the different sessions and the overall congruence [10] of the different elements of the course.

A few students mentioned and appreciated the exercises in their official course evaluation:

> *"It worked well being sent to break-out rooms to do a few exercises together..."*
>
> Anonymous student, *MatN* 2020 Course evaluation

whereas others questioned the efficiency of the format:

> *"... if you could not answer, you were just sort of sitting there."*
>
> Anonymous student, *MatN* 2020 Course evaluation

As the student implies, if one's randomly assigned group does not make progress with (or even manage to properly approach) the assigned problem, the exercise is lengthy and feels somewhat pointless and unrewarding. And while the aforementioned quality of the responses was decent, each group did not always produce an answer on Padlet; supporting the issue raised by the student. A second iteration of these exercise should facilitate a system of hints or additional guidance for groups that are "stuck".

Anectodally, during the classes, some students mentioned during the breaks that they appreciated the "forced" interactions with the other students, as student life could get slightly lonesome during the Covid-19 quarantine. One student even brought it up in the official course evaluation:

> *"... made the class more interactive, which is nice at a time where one is always just sitting at home."*
>
> Anonymous student, *MatN* 2020 Course evaluation

Perhaps, this was the greater success and benefit of adding this this type exercises to this year's edition of the course. And perhaps the social aspect of this exercise does to some extent represent the manner, in which the students will need their mathematical skills in future research projects: in discussions with other students and/or supervisors.

Discussion

While the first iteration of this type of exercise was somewhat succesful, there are a few changes to be made, should they become an integrated, standardized part of the course.

First of all, the issue raised by the student with the exercise being wasted time is concerning and must be remedied. Though I believe this year's online format exacerbated the issue; in a traditional classroom setting, the students would likely have had an easier time consulting the teacher (or other groups of students). That being said, there should - or even must - be a clear route to take for student groups struggling with "getting into" the problem at hand.

Secondly, as written, student responses were collected using Padlet. After a couple of sessions, it became evident that Padlet is somewhat of a double-edged sword when used for student responses as it is here. Padlet is practical, accessible, and easily archived for later reviewing. But due to the nature of mathematics; replies are usually easily and unambiguously labelled as right or wrong. And hence, writing a potentially wrong answer to a presented problem publicly for everyone to see likely constricted some groups of weaker students from presenting their thoughts and considerations.

I believe it is worth reconsidering, whether or not Padlet should really be the weapon of choice for these assignments. That being said, it would have been interesting to ask the groups for a more rigorous evaluation of the other groups' responses and point out flaws in argumentation, counter-examples etc. to emphasize the validation stage of the exercise a bit more; and to perhaps train and test the students in reading and expressing themselves in terms of mathematical rigor.

Furthermore, I am left feeling that there is room for improvement in the institutionalisation part of the exercise as well. Ultimately, the responses provided by the students play too small a role in the section of the exercise - the good responses are quickly reviewed; the mistakes in the less good ones are very briefly visited, but in the end the right answer and arguments are eventually presented regardless of the student responses. One could do another iteration of the breakout room sessions on the same topic. Though in the interest of time, I have a hard time envisioning a better - or more efficient, I suppose - structure.

Another counterpoint to making this type of exercises a recurring teaching activity in this course is worth noting: the reflection exercises are not very well-aligned [11] or perhaps rather incongruent [10] with the exam format in this course, which is a classical written exam based on standard exercises in linear algebra. The skills trained in these exercises are not always directly applicable in the following exam.

In hindsight, there is plenty of room for improvement in the problem descriptions (i.e. the slides in the appendix). Some of the problems need to be reworked as students sometimes got stuck on misperceptions of the problem at hand, or sometimes even misunderstanding the problem entirely (and thus providing a rather convoluted and mysterious answer on Padlet).

As mentioned in the introduction, at times the students question the importance of linear algebra in the nanoscience. At the end of the course, the students were polled on their view on several aspects of the course; among others the pertinence of a linear algebra course in their study programme. As shown in Figure 6, the students replied that the necessity of linear algebra in their study programme is quite apparent to them.

It would have been intersting to compare these answers to similar surveys from previous editions of the course. Unfortunately, these data do not exist. But it is my hope - and belief - that emphasizing the intuitive aspect of linear algebra this year might have contributed to this.

Regardless, I believe future editions of the course should continue attempting to stress the general applicability of linear algebra along with the importance of a multistructural understanding of the field.

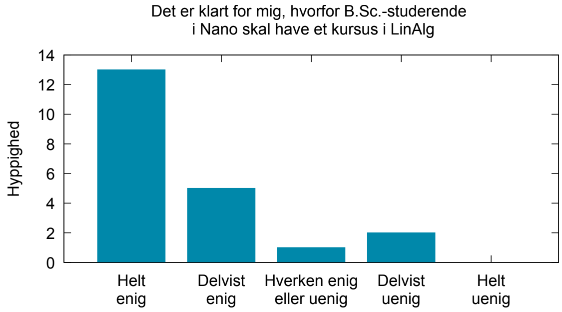


Figure 6: Student responses to *"It is clear to me, why a course in linear algebra is mandatory for nanoscience students"* in the unofficial course evaluation. The response range is identical to the one in Figure 5.

As a final observation, I believe these exercises would scale reasonably well in courses with considerably more students. Though it would be even harder to involve the individual student responses into the institutionalisation phase.

Conclusions and Outlook

The addition of the reflection exercises was reasonably succesful; possibly moreso due to the restrictions placed on the course by the Covid-19 quarantine measures. The student responses to the two presented surveys accompanied by my own impressions and the students' general commitment during the exercises seem to support this conclusion.

Thus, I have every intention of keeping the reflection exercises around for the 2021 edition of the course in one form or another; though as discussed there is plenty of room for improvements in the various aspects of the exercises. The time-wise efficiency of this style of exercises needs to be (re-)evaluated, as they are very consuming and might not benefit the weaker students nearly as much as initially envisioned.

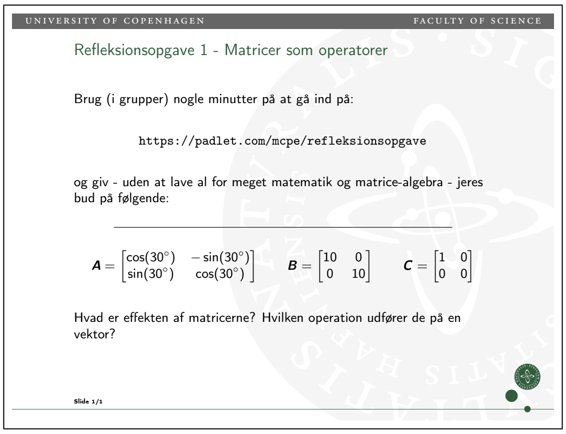
It will be interesting to see if the format works equally well off-line. Obviously, the break-out room functionality will have to be replaced; and perhaps an off-line implementation of this style of exercises should look to a medium other than Padlet as communication/reporting tool.

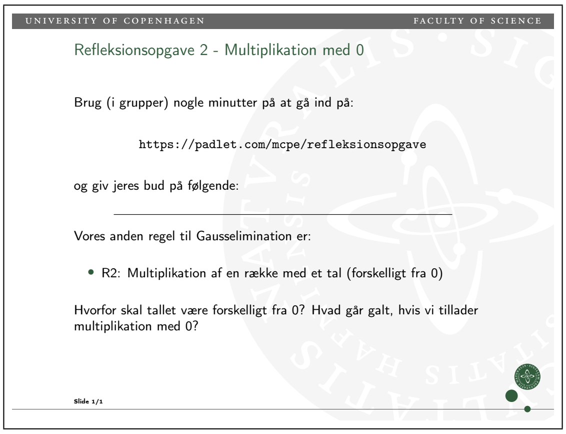
Similarly, the actual problems posed to the students could likely use a rework in light of the lessons learned during the first exposition. Gathering more data on recurring mistakes and misconceptions should aid in this process as well; needless to say, this basis for an element of this type in a course should be an ever-evolving product.

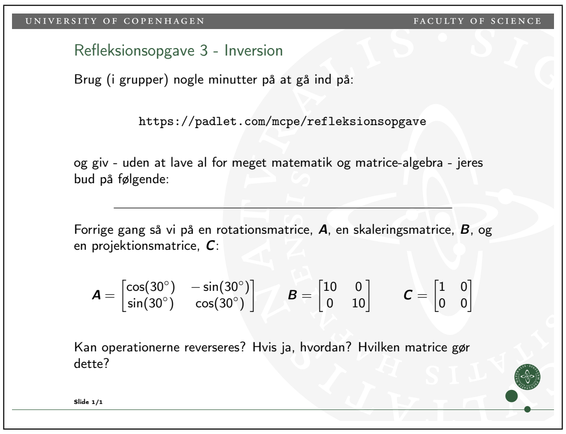
[1] Linear algebra and classical mechanics - Course website (2020). `https://kurser.ku.dk/course/nfyb10019u`.
[2] The nanoscience study programme at University of Copenhagen (2020). `https://studier.ku.dk/bachelor/nanoscience/undervisning-og-opbygning/`.
[3] Biggs & Collis (1982). *Evaluating the quality of learning: The SOLO taxonomy.*
[4] Zoom Video Communications (2020). *Zoom - Video Conferencing, Web Conferencing, Webinars, Screen Sharing.* `https://zoom.us/`.
[5] Brousseau (1996). *L'enseignant dans la théorie des situations didactiques.*
[6] Wallwisher Inc. (2020). *Padlet.* `https://padlet.com/`.
[7] Johnson & Johnson (1975). *Learning together and alone, cooperation, competition, and individualization.*
[8] Showbie Inc. (2020). *Socrative.* `https://socrative.com/`.
[9] Novak, Patterson, Gavrin, & Christian (1999). *Just-in-Time Teaching: Blending active Learning and Web Technology.*
[10] Hounsell & Hounsell (2007). British Journal of Educational Psychology Monograph Series II(4), 91–111.
[11] Biggs, J. (2003). *Aligning teaching for constructing learning.* The Higher Education Academy.

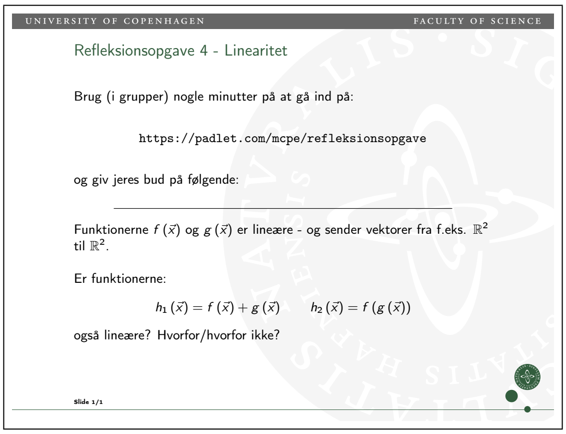
Appendix: Slides with reflection exercise problems

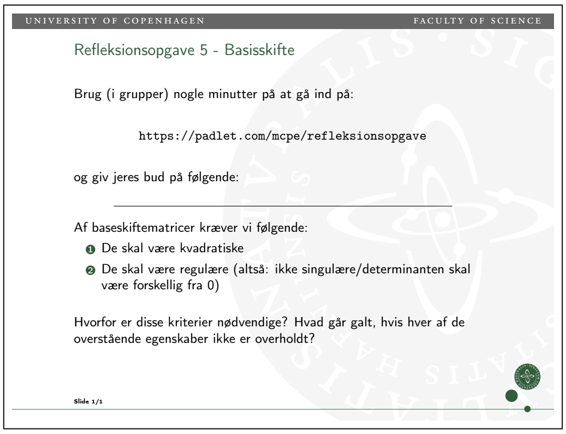
All 10 slides introducing the students to the various exercises can be found below.

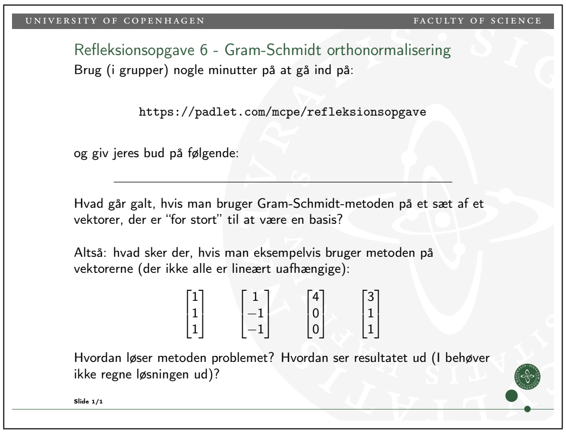












Refleksionsopgave 7 - Egenvektorer og egenværdier

Brug (i grupper) nogle minutter på at gå ind på:

`https://padlet.com/mcpe/refleksionsopgave`

og giv - uden at lave al for meget matematik og matrice-algebra - jeres bud på følgende:

Tidligere i kurset har vi haft kig på rotationsmatrice, $\boldsymbol{A}$, en skaleringsmatrice, $\boldsymbol{B}$, og en projektionsmatrice, $\boldsymbol{C}$:

$$\boldsymbol{A} = \begin{bmatrix} \cos(30^\circ) & -\sin(30^\circ) \\ \sin(30^\circ) & \cos(30^\circ) \end{bmatrix} \qquad \boldsymbol{B} = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix} \qquad \boldsymbol{C} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$$

Hvad er egenvektorerne til de forskellige matricer? Og hvad er de tilhørende egenværdier?

Refleksionsopgave 8 - Egenrum

Brug (i grupper) nogle minutter på at gå ind på:

`https://padlet.com/mcpe/refleksionsopgave`

og giv jeres bud på følgende:

For at finde egenvektorerne til en 2×2-matrice, $\boldsymbol{A}$, tilknyttet en egenværdi, λ, løser vi ligningssystemet:

$$(\boldsymbol{A} - \lambda \boldsymbol{I})\, \vec{v} = \vec{0} \quad \rightarrow \quad \begin{bmatrix} A_{11} - \lambda & A_{12} & 0 \\ A_{21} & A_{22} - \lambda & 0 \end{bmatrix}$$

Hvad gør vi, hvis ligningssystemet kun har en løsning og ikke giver os en familie af egenvektorer? Kan dette ske? Hvorfor/hvorfor ikke?

Refleksionsopgave 9 - Diagonalisering

Brug (i grupper) nogle minutter på at gå ind på:

`https://padlet.com/mcpe/refleksionsopgave`

og giv jeres bud på følgende:

Matricer kan kun være similære med andre matricer med samme determinant. Altså:

$$\det(\boldsymbol{A}) = \det(\boldsymbol{B})$$

hvis $\boldsymbol{A}$ og $\boldsymbol{B}$ er similære.

Kan I komme med:

- Et algebraisk argument for, hvorfor det skal være sådan (hint: tænk på determinanter og baseskift)
- Et geometrisk argument for, hvorfor det skal være sådan (hint: tænk på hvordan $\boldsymbol{A}$ og $\boldsymbol{B}$ transformerer $\hat{\imath}$ og $\hat{\jmath}$)

Refleksionsopgave 10 - Differentialligninger

Brug (i grupper) nogle minutter på at gå ind på:

`https://padlet.com/mcpe/refleksionsopgave`

og giv jeres bud på følgende:

Når man beskriver kemiske reaktioner eller ligevægte med et system af differentialligninger som dette:

$$\frac{d\vec{x}}{dt} = \boldsymbol{A}\vec{x}$$

finder man som regel kun egenværdier lig med eller mindre end nul.

Hvorfor? Hvad sker der, hvis egenværdierne er positive, og hvad er den fysiske/kemiske fortolkning af dette?

Reflection on

Congruence

Martin Cramer Pedersen

The course *Linear algebra and classical mechanics* [1] (referred to as *MatN* from this point) is a mandatory first-year course for students in the nanoscience programme at the University of Copenhagen located in block four. Fifty percent of the course is devoted to linear algebra and the other half is spent on Newtonian mechanics; i.e. the course is part mathematics and part physics. The parts are taught by separate lecturers, and this separation is generally maintained in most aspects of the course. The main purpose of the course is to imbue the students with the tools and theoretical understanding needed for their transition into and participation in subsequent courses in quantum mechanics and statistical physics in the students' second year; one might say it is the quintessential "toolbox"-course.

A glance at the course website and description of the course *MatN* would reveal a seemingly well-aligned first-year course for the nanoscience students introducing them to some essential concepts for later courses in their study programme. According to the course homepage [1], the course is a generic science course at University of Copenhagen consisting of lectures and problem solving sessions.

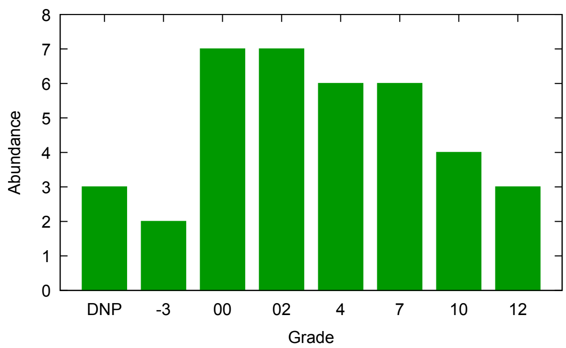


Figure 1: Distribution of grades in the 2019-edition of *MatN*. DNP is an abbreviation for "Did not participate"; meaning a student abstained from the final exam despite being signed up for it. 26 of the 35 participanting students passed yielding a 74% passing rate.

The course concludes with a traditional written 4 hour exam (2 hours of linear algebra, and 2 hours of classical mechanics), but written hand-in problem solving exercises contribute 25% towards the students' final grade. I consider this exam form very appropriate for this course, as it tests the correctness of the students' execution of various solution algorithms taught during the course; in my opinion the exam format is well-aligned with the rest of the course. As shown in Figure 1, the students performed reasonably well in the 2019-edition of the course. The distribution of grades has been reasonably steady in recent editions of the course. The course was rated "A" in 2019 by the nano-science programme study board. However, from the point of view of Blomhøj & Jensen [2], one might argue that the exam and perhaps the course in general tends to focus on skill and some knowledge rather than competencies. This would definitely be a valid criticism, but it would be one that could be directed at numerous mathematics courses.

In this reflection, however, we shall discuss the course and its congruence in relation to itself and the nanoscience programme at University of Copenhagen as a whole. The course is known as a "problem course" in the study programme and has been so for years; though this is mostly visible from "The programme perspective" as we shall see later. Anecdotally, I have heard students refer to block four as the "killer block" of the first year.

Hounsell & Hounsell [3] identify a couple of issues and concerns that are very applicable in the context of courses taught by several teachers: inconsistent practices and ensuing complicated communication. The linear algebra-part of the course is taught in a flipped classroom/just-in-time-teaching [4] style with a substantial amount of the preparation being videos for the students to watch ahead of class. The classical mechanics-part of the course is taught using the popular *Mastering Physics* web-based teaching environment. Both are seemingly working well, but this does put strain on communication and does at times confuse the students; as an example assignments in linear algebra are handed in via University of Copenhagen's Absalon system, whereas the physics assignments are submitted via the *Mastering Physics* system.

On a more topical level, the course is - in my opinion - rather incongruent with itself in the sense that the classical mechanics-part of the course has no relevance to the linear algebra-part and vice versa. Several students point this out in the evaluations of the course:

> *"Split LinAlg and Mechanics in two, so one can concentrate on each topic individually."*
>
> Anonymous student, *MatN* 2019 Course evaluation

> *"A pity that the course contains two topics. It would have been preferable if they had been separate courses."*
>
> Anonymous student, *MatN* 2019 Course evaluation

One student even identifies the structure of the course as impeding the learning process:

> *"It is limited how much one can learn about each topic when the course is kind-of two-in-one."*
>
> Anonymous student, *MatN* 2019 Course evaluation

It is also important to recognize that the students get a single grade describing their efforts and abilities in what is essentially two separate courses. And we have to ask ourselves: is that meaningful? Naturally, a grade is necessarily a great simplification of a students' abilities of the various material within a course. But at what point are we averaging over too much material for a single number to be sufficient? In fact, some students display considerable discrepancies in their abilities within the two parts of the course. Is it really meaningful to assign one grade in these cases? In light of these considerations, the exam is not particularly congruent with the course itself.

Naturally, this structure also invites students to deploy learning strategies that are extremely mis-aligned with the nanoscience programme as a whole. In casual, after-lecture chat, some students confided that they were planning to "just score a few points" in the classical mechanics part of the course in the hopes of excelling at linear algebra and thus achiving a passing grade in that manner. I cannot exclude that other students did the opposite. In these examples, a student executing this learning strategy can end up with a passing grade with close to zero understanding of linear algebra. The exam might fall into the "reliable-but-not-valid" category.

Obviously, the tempting solution to offer up is to split the course in two, separate courses. However, this maneuver would necessarily remove an elective course in the programme outlined in Figure 2) and deprieve the students of some of the flexibility in tailoring their education, a trait which the nanoscience education claims as one of its pillars [6].

Before moving on, let us glance at the nanoscience programme at University of Copenhagen shown in Figure 2. As mentioned, the primary objective is linear algebra part of *MatN* is preparing the students for the two courses in quantum mechanics, *Nanokvant* and *Kvantefænomener i nanosystemer*, whereas topics covered in the classical mechanics part of the course are needed for the courses *Nanotermodynamik* and *Molekylær statistik*.

	Blok 1	Blok 2	Blok 3	Blok 4
1. år	Nano 1 - introduktion til nanovidenskab	Introduktion til matematik for de kemiske fag	Sandsynligheds-regning, dataanalyse og indledende ellære	Elektromagnetisme og elektronik
	Organisk kemi i naturvidenskab		Almen og uorganisk kemi	Lineær algebra og klassisk mekanik
2. år	Nanotermodynamik	Nanokvant	Kvantefænomener i nanosystemer	Molekylær statistik
	Nanobio 1	Nanobio 2		
3. år			Nanobio 3	
			Bachelorprojekt	

Figure 2: The course plan for the B.Sc. programme in nanoscience at University of Copenhagen [5]. White spaces are elective courses, and grey spaces are restricted, elective courses with which the students specialize themselves within the biological, chemical, or physical subdisciplines of nanoscience.

And this brings of to the crux of the matter. The students learn sufficient linear algebra to pass an exam (many helped a lot by the 25% of the grade they accumulate during the course). But ultimately, several student finish the course with a shallow learning experience in both linear algebra and classical mechanics. As such, this problem does not become apparent until later in the study programme, as the teacher of the course *Nanokvant* explains:

> *"The main issue is that the students are rather weak in linear algebra. Most of them seem to have forgotten."*
>
> Course responsible, *Nanokvant* 2018

A student evaluation agrees with this assessment (and recognizes the danger of lacking deep understanding of core concepts):

> *"... it all became a bit shallow - especially when compared to how much we will be using these things in the future"*
>
> Anonymous student, *MatN* 2019 Course evaluation

I will start by adressing one particular (but likely insufficient) course of action that could address this issue: the gap in the study programme in Figure 2 between the courses *MatN* and *Nanokvant* is likely quite detrimental in this regard. One is tempted to refer to this as the opposite of the philosophy behind "just-in-time" teaching [4]. Shuffling the courses in a way that schedules *Nanokvant* right after *MatN* would likely benefit the students; in particular the ones already struggling with linear algebra.

However, I fully understand if a student leaves the course with an insufficient knowledge of the key concepts of linear algebra needed to understand quantum mechanics. The course is essentially a sprint towards a few conceptually difficult but essential threshold concepts [7, 8]: eigensystems, inner products, and change-of-basis with little time for digestion and repetition. The classical mechanics part has the same structural challenges and accompanying problems from sprinting to threshold concepts.

For linear algebra, one facet of the problem is easily stated and quantized using the SOLO taxonomy [9]: a large group of students achieve unistructural understanding of the three threshold concepts outlined in the previous paragraph, whereas the students need to reach a multistructural understanding of these to successfully transition into learning quantum mechanics. This statement can be supported by considering the fact that a large group of students struggled at answering the conceptual questions in the exam, whereas they generally succeed at applying the concepts in algorithmic manners.

On the positive side of matters, by now we have indeed identified that *MatN* is a topically congruent with the nanoscience programme. The methods and theory taught in the course are critical. And the students tends to recognize this (possibly with the help from older students), which in turn makes them very dedicated and engaged learners. That being said, changes to overall curriculum are in my opinion unnecessary - and in fact probably ill-advised.

Adding to the previous point, I suspect that the course is largely successful due to the students putting in strong efforts after hearing older students describe their struggles in this course as well as rumors of its relevance later on. Quantum mechanics is well-known to be a technically demanding topic to understand and this reputation likely serves this preliminary course well.

Another structural problem complicates the course further. In the introductory mathematics course *Introduction til matematik for de kemiske fag* in block three, the students are introduced to the powerful computer-based algebra software Maple. This introduction is not embraced by *MatN* (or any later courses) in any manner for a variety of reasons - the main one being the already too-intense curriculum - and this complicates the course in an strange manner.

First of all, the students are split in two group. Those able to deploy Maple for aiding them in solving problems on their own are free to do so, but this often happens at the expense of conceptual understanding of the various solution methods as they miss out on hands-on experience by letting the software "do the math". Though one could argue that this is in fact more in line with how they will be using linear algebra in future contexts. Those having left the previous course with little-to-no proficiency in Maple are stuck doing these problems by hand. While this is undoubtedly better for them in the long run in terms of deep learning, it does at times split the student group in two. *MatN* attempts to remedy this by requiring detailed calculations in the hand-ins, and by not allowing the students to bring laptops to the exam.

To make matters more complicated, for most of the students this will likely be the last time they use Maple. The software is not particularly popular ourside of educational settings, and in later research projects the students are more likely to encounter other software packages and solutions. In terms of alignment and congruence, there seems to be no simple way out here; the nanoscience programme should consider either embracing or abandoning Maple as a whole.

I will emphasize another aspect in which the course lacks congruency with the nanoscience programme. Essentially, the students experience linear algebra to have little subjective relevance (but plenty of objective relevance) as is likely the case for many "toolbox" courses. However, as indicated earlier, the topic is essential for the students' future progression in the programme; this is stated explicitly at the beginning of the course with a few, quick examples of application, but this is not revisited during the actual course.

At the exercise sessions, the students do standard linear algebra problems with little consideration to the manner in which, they might be employing linear algebra at a later point in their study/career. This is necessary for the learning of the algorithmic nature of the topic and as such I believe that exposing the students to classical linear algebra problems is essential for their understanding of the material. I doubt there is any other way to learn the basics of this field.

Simply put, I find that this conflicts a bit with philosophy of the nanoscience programme at University of Copenhagen. From the programme description at the "Teaching and structure" section of the programme's website [6], one reads that:

> *"In the first courses of the bachelor's education, you will be testing the theories in practice through lab exercises and experimental projects."*
>
> Nanoscience programme description, 2019

The over-arching idea of the programme is that the students should learn to apply ideas to whatever their field of interest might be. The website lists medicine, biotech, or electronics as potential choices. And in its current incarnation, this course does not really allow for this application of its concepts - the students will simply have to trust that this relevance and applicability will emerge later on. Using the vocabulary from Hounsell & Hounsell [3], I would argue that this conflicts with the students' backgrounds and aspirations. They likely chose to study nanoscience over e.g. physics or chemistry as nanoscience is known to be a more application-oriented programme.

One can imagine more research-like or perhaps rather research-based "lab exercises" in linear algebra, in which the students would try applying the concepts in practice; contrasting the more theoretical nature of the problem solving sessions. To maintain relevance, these would likely be computer-based (though likely not based on Maple but rather a more research-relevant competitor) and perhaps the course could be extended to include a component of scientific computing. However, the current schedule does not allow for this. The nanoscience programme at University of Copenhagen has strong research-based teaching as a central ambition [6], and I would argue that including problems in the direction of applied linear algebra would be well in line with this philosophy. Thinking back to the introduction, this would to some extent embrace the desire and need for more competence-focused teaching [2].

In conclusion, *MatN* exhibits a strange mixture of strong congruence and equally strong incongruence with itself and the encompassing study programme in nanoscience at University of Copenhagen. In my opinion, the course relies on the students being very dedicated and on them beginning the course already understanding its relevance and importance. The exam and curriculum seems in line with the overall purposes of the course, but I believe there is room for improvement in terms of subjective relevance and congruence with student ambitions.

---

[1] MatN course website (2020). `https://kurser.ku.dk/course/nfyb10019u`.

[2] Blomhøj & Jensen (2003). Teaching Mathematics and Its Applications 22(3), 123–139.

[3] Hounsell & Hounsell (2007). British Journal of Educational Psychology Monograph Series II(4), 91–111.

[4] Novak, Patterson, Gavrin, & Christian (1999). *Just-in-Time Teaching: Blending active Learning and Web Technology.*

[5] Nanoscience study programme at University of Copenhagen (2020). `https://studier.ku.dk/bachelor/nanoscience/undervisning-og-opbygning/`.

[6] Bachelor i nanoscience (2020). `https://studier.ku.dk/bachelor/nanoscience/`.

[7] Meyer & Land (2006). *Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge.*

[8] Entwistle (2009). *Teaching for understanding at university.*

[9] Biggs & Collis (1982). *Evaluating the quality of learning: The SOLO taxonomy.*

Reflection on

Feedback to students

Martin Cramer Pedersen

In the context of traditional problem solving in physics and mathematics, summative feedback is traditionally a somewhat simple and straightforward task: adding up the correct answers and perhaps pointing out where the student might have gone wrong; and finally assigning a grade or simply stating e.g. percentage of correct answers to the stated problems. Usually accompanied by a few lines of text explaining the reasoning for the grade and areas that need improvement. The main advantage of this method is that it is reasonably efficient - in particular when dealing with a large number of students.

It believe it works well in most cases; to me one of the main pitfall emerges in the case of weaker students, where the bluntness of this method can be hard to absorb. Without appropriate an appropriate guidance of where to improve (and perhaps equally important where not to put one's focus) and formative feedback, assigning e.g. "34% correct answers" to a student can be devastating for a student's self-esteem and professional development. As Young (2000)[1] explains, negative feedback is less welcome among students with low self-esteem; and while this is technically objective feedback, the statement likely still stands.

Similarly, I have found it hard to give substantial formative feedback in similar cases; in particular in the extreme cases where the student either a) solved every problem correctly or almost correctly and consquently scored close to 100% or b) where the student failed to solve the problem(s) at hand at a fundamental level.

In the first case, I usually find myself simply providing the student with "Good, well done, nicely presented" or a similar nice, but not particularly formative statement. In the latter case, providing formative feedback is equally hard as the formative feedback becomes so closely linked to the summative; e.g. "Practive by solving similar problems" or "Invest your time in studying the theory begin the correct approach". While seemingly formative, I fear these pieces of advice do not offer the student much more than pointing out a mistake in a derivation.

I suppose part of the problems stems from the fact that the process (say: a derivation) and the product (say: a solution to the problem at hand) are closely related. If one is wrong then so is the other; though I think most educators do try to separate arithmetic mistakes from conceptual or algorithmic mistakes when grading.

As in a previous reflection, perhaps more open questions could be an approach to adressing this. Ideally, this would allow more focus on the thought process and less on the right or wrong answer. Rather than assigning the students with the usual task of the finding the solution to a problem, one could perhaps ask them to explain the steps in a derivation; perhaps even the derivation of another student.

Though I fear this style of problems might conflict with the students' perception of methodology in e.g. mathematics and eagerness to comply, which has been ingrained in their understanding of e.g. mathematics since early elementary school; cf. the "What is the captian's age?"-example. However, this type of problems would in turn have to be aligned with an eventual exam. And it would certainly increase the time needed to grade the assignment.

Finally, I cannot help but worry that fundamentally changing the manner in which problems are assigned to accommodate the harshness of feedback to weaker students might happen at the expense of the stronger students who succeed in the traditional style of problem solving. And finally it begs the question: would this type of problem truly teach the students to execute the correct approach to the problem?

That being said, the traditional exercises in some branches of mathematics have not changed for centuries so perhaps there is some room for improvement to be found.

[1] Young (2000), Journal of Further and Higher Education 24(3), 409-418.

Reflection on

Research-based teaching

Martin Cramer Pedersen

I found the account by Sørensen[1] on the implementation of research-based teaching into the first-year course Nano1 interesting for a variety of reasons as I believe it serves a number of purposes in the nanoscience education. First of all, it imbues the students with a better understanding of the still-young discipline nanoscience through an introduction to the types of research done in this field. Nanoscience finds itself at the intersection of physics, chemistry, and biology, and I believe this mandatory formation of professional identity could be much needed for students not entirely sure of how to navigate this area of science. In that regard, it also induces the students to speculate on future specializations and subdisciplines they find interesting within the field.

Sørensen frames the extent of the amount of investment and experimentation (and perhaps also the cooperation and open mindset from the study board) needed to refurbish an existing course into a research-based one. The development and reception of the course is presented as a success (which I believe it to be), though I do take note of the concern of some students' occasional lack of hard, secondary skills needed to successfully complete the research projects.

One of the over-arching themes in the first part of the pedagogics course was exposing the students to the relevance of the material being taught; and bringing research into teaching seems like a solid way of doing this. Naturally, this is not a trivial exercise; and some courses will lend themselves to this revamping better than others. My particular interest in this topic is in discussing the extent to which the "traditional" toolbox courses can be revamped into more research-based courses. But as someone who struggles to bring subjective relevance into his teaching, the proposition of research-based teaching seems promising, though I wonder how to implement it in a generic course.

The course developed by Sørensen approaches the concept in a direct manner: making the students conduct actual, small-scale research projects; and evaluating them based on the process and reporting. However, in e.g. a calculus course, I struggle to envision a way to expose the students to current research in the fields in a meaningful manner. But perhaps there is something to be said for altering the style of the tutorials and homework problems presented in such courses.

The paper certainly made me question the types of exercise, I expose the students to. Perhaps exercises focussing on computer-based calculations are preferred as they mimick the manner in which mathematics is usually applied in a research setting. Or perhaps one could pose low-level, practical problems that emerge in a research setting and have the students do literature studies of available solution methods. An example could simply be: how do we determine the characteristic directions of a crystal or simply some point cloud? The hope would be that the students discover the literature on principal component analysis. In this example, the students would have to have the necessary understanding of linear algebra to appreciate the method as well; and ideally the students would then get an idea of how linear algebra is used in practice in research.

Needless to say, the danger here is that some students might not discover the "correct" answer. And I suppose this emphasizes what I assume to be one of the main concern with research-based teaching. Some fields or research have an inherent amount of trial-and-error and lots of failures. While these failures are essential in the research (and learning?) process, how does one manage them in a setting such as the one previously outlined? Sørensen mentions that the students are mostly evaluated (and recieve feedback) on the research process and less so the emerging results, but is this transferable to e.g. the literature study from before. What does one tell a student that find a different, good, but less-than-optimal answer to the research problem? Perhaps one is better off with very open research questions in this format.

[1] Sørensen (2015), `https://www.ind.ku.dk/publikationer/up_projekter/2015-8/PedagogicalProjects2015.pdf`

EDUCATIONAL FELLOWSHIP SCHEME

2016 Associate Fellowship (AFHEA) Application Template

The ANU Educational Fellowship Scheme (EFS) is accredited to award all categories of Higher Education Academy fellowship, to provide professional recognition of your reflective practice of university teaching. The AFHEA guide and your EFS mentor will help you use this template to write your application.

Section 1. Application Cover Sheet – completed, signed and scanned

When complete, please consolidate all parts of your application into a single PDF—with the coversheet (completed, signed and scanned) at the front and references at the end—and email to efs@anu.edu.au

Section 2. Overview of my Teaching / Learner Support Experience

Academically, my background is mathematical physics, in which I received my Ph.D. from the University of Copenhagen in 2014. My experience with teaching at university level stems from tutoring and instructing in several courses, co-supervision of bachelor projects in neutron scattering and biophysics, as well of developing tools and exercises for a graduate course in neutron scattering.

As a natural consequence of my background, I have mainly been teaching problem solving and computer scientific lab classes - usually for groups of 20 to 30 students. The background of the students have varied from graduate students specializing in a particular branch of physics to first year students in other fields. Specifically, I have been an instructor in the 2011- and 2012-editions of the undergraduate course Mathematics and Data Processing, the 2012-edition of the undergraduate course Biophysics, and the 2013- and 2014-editions of the graduate course Neutron Scattering in Experiments, Theory, and Simulation, in which I also developed student exercises and tests. All courses were hosted by the University of Copenhagen.

Teaching experience is a mandatory part of the Danish Ph.D.-programmes, and the aim is for a candidate to spend 540 hours on teaching and teaching-related activities. The quality is ensured via mentoring from professors and a high degree of feedback from students.

Section 3. My Philosophy of Teaching and Learning

My motivation for teaching mathematics and physics stems from my own fascination with the fields, and my desire for others to experience the same fascination. To me, the elation associated with solving a complex problem, understanding a difficult concept, or executing and algorithm correctly is unparalleled; and as a teacher, I feel as if one shares the learner's sense of success, when he/she accomplishes one of these tasks. In a sense, I suppose I find the challenge of communicating an abstract concept to someone else somewhat similar to the technical challenges in my field.

I am inspired by the literature of Biggs (Biggs, 2003), which differentiates between declarative and functioning knowledge in his descriptions of Intended Learning Outcomes and stresses that the aim of teaching should be to encourage students to turn their declarative knowledge into functioning knowledge. I find this to be a great description of the overall goal of education in physics and mathematics; in these fields, functioning knowledge is paramount; and I have aimed to structure my teaching with this in mind. Thus, I strive to apply visualisation and animations as educational tools. When dealing with the aforementioned abstract concepts, a picture is worth a thousand words. Although in this context, it is likely more appropriate to express worth of animations, drawings, renderings, diagrams, etc. in terms of number of equations, they can explain. Admittedly, this is hardly a controversial opinion, yet I find that it supports the ideas outlined by Biggs well.

I would use words such as pragmatic and reductionistic and always focused on the technical and theoretical aspects of the topic at hand. All of which reflect my own way of engaging with a problem or task. I often find myself using simplifying analogies and examples in attempts to explain abstract concepts, as this allows one to highlight the essential (theoretical) aspects in whichever idea or concept, one is trying to convey. And although I have seen it quite a few times at this point in my career, I still take great joy in watching a student’s enthusiasm and pride, when you tell them that they have grasped an abstract concept and solved a complicated problem with their newfound knowledge. These moments make the preparations worth it.

In terms of inspiration, I will go with the choice, the vast majority of physicists would select: American Nobel laureate Richard Feynman, nicknamed "The Great Explainer", who fathered (or certainly popularised) this style of example-based yet theoretical variant of physics education.

Amongst Feynman's many contributions to modern physics, in particular his invention of the so-called Feynman diagrams exemplifies exactly this notion: a simple diagrammatic notation representing (and accounting for) complicated calculations of particle interactions. Which I find to be a great example of converting declarative knowledge to functioning knowledge.

As a second source of inspiration, I will quote the Danish Nobel laureate Niels Bohr:

> *"We are suspended in language in such a way that we cannot say what is up and what is down."*

Unlike Feynman, Bohr is not particularly recognised for his prowess as an educator, yet the quote stresses what I find to be a common hurdle in education in the STEM-fields: the notion of establishing a common language (or perhaps rather vocabulary) with the students; a language that is capable of describing and communicating very abstract concepts in a simple manner to students, whose academic background might be considerably different from one's own.

Section 4.1. Reflective Narrative on first Area of Activity
A3 Assess and give feedback to Learners

During my four years as an educator/tutor at the University of Copenhagen, I have been teaching and thus providing feedback for roughly 120 students via the courses mentioned earlier in this application.

Providing feedback to students has always been a complicated endeavour for me - and I have often felt as if I was balancing on a knife's edge. On one hand, one wants to maintain a professional and honest relationship with the student, which implies that one should say things the way they are; tough though it may be. On the other hand, due to the abstract nature of the material, it is easy to completely discourage a student by pointing out every single mistake in a solution; and naturally, this must also be avoided. I assume this is particularly true in the fields of physics and mathematics, as attempted solutions are usually easily categorised as right or wrong with little room for interpretation. This issue is related to the problem discussed in the literature by Boud (Boud, 1990), as he accuses teachers in higher education of "turning the assessment into the curriculum"; i.e. to focus on the correctness of a presented solution rather than the understanding of the material behind the presented solution. Similarly, Hudson (Hudson, 1960) demonstrated that performing well in a given assessment of scientific prowess does not necessarily translate to general scientific prowess.

I have had to employ surprisingly different strategies in my various teaching roles because of this. Due to the difference in background and learning strategies (and perhaps enthusiasm for the topic in general), one simply has to conduct feedback sessions for the individual students in considerably different manners [V1]. And this is not only due to the academic properties and abilities in the class, the social aspects surrounding groups of students and their grades weigh heavily in this context. One aspect in particular, I find to differ wildly students in-between, is their interest in (or perhaps rather benefit of) having their feedback directed at their understanding of a given example/problem or at their understanding of the underlying theories. Roughly speaking, one type of students responds considerably better to having their mistakes pointed out and corrected and figure out themselves, which conceptual, underlying mistake they made, while another type prefers the opposite. For me, assessing this particular quality in each student is an important initial step in the planning of further feedback to the individual student [K3, V1]. In a sense, this is one of the inherent pitfalls in example-based problem solving classes. As an example, I have had to point out a classical error to (numerous) students by telling them that "you have made a mistake here; integration by parts does not work like that; be careful when you define f(x) and g(x)". For some students, this is sufficient feedback for them to reattempt the problem, whereas others promptly reply: "but what is the actual mistake". The key is their need for specificity.

According to Biggs (Biggs, 2003), the challenge for the educator is to assess, how far a given student is in the process of turning declarative knowledge into functioning knowledge – and equally important, which approach the student is using to accomplish this. Another challenge, I have often found myself facing in a classroom, is the task of limiting the feedback; in terms of depth, in terms of complexity, and to be pragmatic: in terms of time consumption. Ideally, one wishes to provide concise and almost surgical feedback to a student's attempt at a solution to problem, but in practice one can easily fall into the trap of going out on some tangential explanation of a concept to a single student; naturally, this is not an optimal way of conducting a problem solving class [K2, V4].

German-born Nobel laureate Albert Einstein summarises the problem in the following quote:

"Teaching should be such that what is offered is perceived as a valuable gift and not as a hard duty."

I can certainly relate to this, yet as Boud (Boud, 1990) points out as well, in the context of performance- and economy-driven higher education, one simply might not have the time and resources available to accommodate this simple criteria. In my experience, students in higher education are generally enthusiastic about the material, they are being taught. And this makes for a great atmosphere in class. Thus, I have always found it heart-breaking to have to cut an explanation or discussion short in the interest of time, the other students, or the aforementioned criteria of conciseness. Unfortunately, this is the nature of the field, and I assume that most educators in higher education face this issue on a daily basis [V4].

As an educator, I now realise the importance of feedback in a considerably different manner than as a student. Like most students, I think I merely perceived it as an extension of a given grade in a given course. However, once I found myself in the role of the educator, it dawned on me how hard it can be to assess the impact of one's methods, and how mutually beneficial honest feedback can be for both students and educators.As an example, my colleagues and I set up a series of online tests in a course on neutron scattering. As the students completed these tests, we would monitor their every click and record their responses. During my first involvement in this course, we would simply use these responses to assess the students' understanding of the material [K4].At some point, a student approached us and asked, if we could address some of the errors he thought he made during these tests. We felt somewhat dumbfounded for not realising this possibility ourselves - we had ignored a gold mine of valuable material for feedback tailored to the given students. In the rest of the course and in the later editions of the same course, I would identify trends - preferably in the mistakes, the students would make - and have a feedback lecture/discussion session in the coming class, wherein I would rephrase the problems, which had troubled the students, and discuss the answers [K1, A2]. Not only did this allow me and my colleagues to correct misunderstandings of the material in their infancy, it really allowed the course itself to iteratively develop into a much more concise and directed version of itself [V3, K5].

In my opinion, this is a time-consuming approach to giving feedback, yet I have found it to be efficient and beneficial, and the reactions from the students have been generally positive. It should be noted that this particular method is somewhat invasive as well - all of this was done with the students' explicit approval. Furthermore, we experimented with placing recorders in the groups of students attempting to solve a problem. We found that all this really accomplished was completely silencing the chatter and discussion in the group of students; in retrospect, this was perhaps not a surprising result - naturally, there are levels of invasiveness that are simply too destructive. The important lesson to take from this is a classical one from the world of physics (and science in general): one cannot investigate a system without disturbing it. One of the explicitly stated goal of this course was to develop a purely-online edition of the course in MOOC-style, and a lot of mine and the other involved parties' attention was devoted to developing scalable exercises, problem sets, and quizzes [V2, V4]. Naturally, in a MOOC-sized edition of the course, the individual feedback would have to be scaled back considerably.

Were I to give my former self three pieces of advice before setting out on the task of teaching physics and mathematics at university level, I would list the following: be aware of the individual student’s need for feedback; be aware of the technical challenges and opportunities that arise in modern higher education; and make sure to encourage (and participate in) an informal and relaxed atmosphere, as this produces livelier and more productive interactions in class.

Section 4.2. Reflective Narrative (750-1000 words max) on second Area of Activity

A4 - Develop effective learning environments and approaches to student support/guidance

The importance of being able to explain scientific concepts was immortalised by New Zealand-born Nobel laureate Ernest Rutherford:

"An alleged scientific discovery has no merit unless it can be explained to a barmaid."

Ignoring the impolite and sexist slight concerning barmaids' abilities for understanding physics, I find that this quote emphasises one of the central issues in modern science: scientists' inability to explain science - in layman's terms as well as in professional expositions. Interestingly, Rutherford also - perhaps unintentionally - highlights the natural connection between education and dissemination in the natural sciences. Communication is an issue with every single student. I recall an experience from teaching undergraduate mathematics problem solving classes. I had to introduce the so-called logistic differential equation. Some students grasped the concept from the basic algebraical description, other students responded considerably better, when the concept was introduced as a population growth model, and others did not understand the concept until I plotted the solution and identified the various parameters graphically [K2, K3]. As earlier, in order to succeed in explaining a concept, this is a preference in each student, I find it vital to identify. I find that this is one of the arts in education in physics and mathematics: knowing when to stray from the beaten path in terms of explanations and vocabulary. It might sound unprofessional, but I would wager that most teachers do so all the time; and the explanation is simple: students are simply different.

And just to cement the point, I am trying to make, I will quote French mathematician Henri Poincare to establish the similar problem in mathematics:

"Mathematics is the art of giving the same name to different things."

One of the ways, I have tried to accommodate this disparity in language and in learning strategies, is to try to encourage a relaxed and informal environment (and tone) in these classes - specifically, an environment, wherein it is acceptable (or perhaps even encouraged) to make mistakes and to request the help of others. This is not an easy task; I find it particularly hard to accomplish with freshmen, as they might not know each other well, or might still suffer from start-of-university shell shock [V1]. With experience, one learns to design exercises (and the sessions themselves) so that students are effectively forced to interact, which helps overcome his obstacle. This can be done by e.g. group discussions of a problem that is vaguely posed or too hard for the individual student. I will note that for the students that wish to continue their career in academia (and in the industry, I suppose), being able to ask peers for advice and guidance is a must-have skill, so in a sense it is the duty of the educator to develop it [V4].

As most academics will tell you, the importance of having the correct approach to student support becomes painfully evident in the context of supervision (or in my case merely co-supervision) of student projects [A1]. I find it especially true in these one-to-one situations that if one fails to create the aforementioned atmosphere of informality, students might become unresponsive out of fear of demonstrating lack of understanding. My experience in student project supervision and in particular the aforementioned course on neutron scattering has shown me that students respond very well to being exposed to cutting edge scientific methods and agendas. In this course, students were simulating worldleading instruments used in neutron scattering experiments. This is the only way of familiarising students with this type of experiments, as training session would be unfeasibly expensive - this is simply the nature of experiments conducted at large scale facilities [K2, V4]. When we exposed students to our own, unpolished simulation codes, I have found students to "drop their guard" upon realising the mortality of their educators [K1, V3]. Amongst many other reasons to do so, I think it serves the purpose of promoting the student to the status of colleague, and I would very much encourage colleagues not to hesitate to show students their own, imperfect examples from ongoing research. This highlights an aspect, we have addressed earlier in this application: the need for a casual and informal atmosphere; in my experience, students respond well to this.

As another example of the importance of caution when designing learning environments, I will once again resort to my experience with developing web-based exercises for the course in neutron scattering. As the exercises were meant to be stand-alone, and seeing as no student should get stuck on the problem being presented, my colleagues and I spent a good chunk of the development time discussing and structuring hints [A1]. First of all, we worked from the paradigm that hints should only appear on the given student's active request. We would monitor the students' progression during the problem solving - and specifically, at which problems they requested hints, and how quickly they would skip to the next hint after seeing one [K3, K4]. The goal was to construct a sequence of hints that would prompt the student to stop at each one and reattempt solving the problem. Specifically, the idea was to guide each student through a problem, which would be tailored to their understanding of the material. I found the results of this endeavour to be quite interesting - and if anything, it highlighted the vast difference between different students' approach to a problem; some one used the hints to check their results, whereas others instantly requested all hints to a problem. We obtained wildly different results, when varying the hint structure. But we certainly learned a lot in terms of developing streamlined hint structures in many of the exercises [V3].

I will end this narrative on that note. It stresses the importance of understanding and awareness of one's communication with the students, which I have tried to make the common theme in this narrative. In my experience, this is the key to a mutually beneficial student-teacher-relationship, and I doubt many would disagree. In physics and mathematics, I find this particularly important due to the abstract nature of the disciplines and essential, if one is to succeed as educator.

True to the form of this application, I will conclude by quoting Richard Feynman, who was introduced in the beginning of this section:

> *"The correct statement of the laws of physics involves some very unfamiliar ideas which require advanced mathematics for their description. Therefore, one needs a considerable amount of preparatory training even to learn what the words mean."*

Feynman's words embrace the spirit of this application nicely. In order to educate students for careers in science, not only is it essential to imbue them with an in-depth understanding of the discipline in question, it is also essential to train them in the language and vocabulary associated to their field as well as the use of these, if they are to succeed outside the classroom [V4].

Works Cited

Biggs, J., 2003. Alignment teaching for constructive learning. *The Higher Education Academy,* pp. 1-4.

Boud, D., 1990. Assessment and the Promotion of Academic Values. *Studies in Higher Education,* 15(1), pp. 101-111.

Hudson, L., 1960. Degree Class and Attainment in Scientific Research. *Brit. J. Psychol.,* 51(1), pp. 67-73.

Section 5. Contact details for two (2) referees.

The EFS will contact your referees when you submit your application. They will be sent a copy of your application and will be asked to submit a reference for you online against Descriptor 1.
A copy of each reference will be sent to you.

If you have a Certificate of Completion for Foundations or PTD, please attach it at the end of the application PDF, and supply the name of only one referee.

Referee 1
Name: Dr Cormac Corr
Position: ARC Future Fellow and group leader
How referee knows you: Colleague at RSPE
Email contact: cormac.corr@anu.edu.au

Referee 2
Name: Dr Paul Francis
Position: Associate professor
How referee knows you: Colleague at RSPE
Email contact: paul.francis@anu.edu.au

FACULTY OF SCIENCE
UNIVERSITY OF COPENHAGEN

Course certificate

Martin Cramer Pedersen

Name

07-11-1985 00:00

Date of birth

Supervision of BSc and MSc students

PhD course

5627-20-08-12

Course no.

1,00

ECTS

Lene Møller Madsen

Course Organiser

This course was offered by
the PhD School of SCIENCE,
University of Copenhagen.

24 November 2020

Final course date

Morten Pejrup
Head of the PhD School of SCIENCE

UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE

Certifcate

This is to certify that

Martin Cramer Pedersen

Has completed a course at the University of Copenhagen in

Supervision of PhD students

GENERAL CONTENT
This course consists of lectures, discussions and practical exercises over two days comprising the following topics:

Aligning expectations
Collegial help in supervision
Roles and responsibilities in supervision
Writing process and Feedback
Motivation

Katrine Lindvig

Department of Science Education, Faculty of Science

12. december 2020

Assistant Professor
Martin Cramer Pedersen
Niels Bohr Institute
University of Copenhagen
October 13, 2020

Teaching assessment for Assistant Professor Martin Cramer Pedersen

DEPARTMENT OF SCIENCE EDUCATION
ØSTER VOLDGADE 3
1350 KØBENHAVN K

+45 353 20394

This teaching assessment has been prepared in connection with participation in the Teaching and Learning in Higher Education Programme (*Universitetspædagogikum*), run by the Department of Science Education at the University of Copenhagen.

The Teaching and Learning in Higher Education Programme involves a total of 175 hours' work. The programme comprises a theoretical part (110 hours) and a practical part (65 hours). The theoretical part incorporates the participants' own teaching while working on a number of central topics. In the practical part of the programme, the participant receives supervision from a department supervisor appointed by his or her department and an educational supervisor appointed by the Department of Science Education. This assessment is related to the practical part of the programme and a separate diploma is issued upon completion of the entire programme. The assessment is partly based on the undersigned supervisors' observations of the participant's teaching as well as on meetings between the participant and the supervisors held before and after observation of the teaching sessions. In addition, it builds on the teaching portfolio prepared as part of the programme.

The practical part took place during multiple supervision sessions in 2020. Department supervision was conducted by Professor Jesper Nygård and educational supervision was conducted by Associate Professor Ricardo Karam. The following assessment is based on observations of online lectures given by Dr. Pedersen in the course *Linear Algebra og Classical Mechanics (MatN)*, offered to Nanoscience Bachelor students at the Niels Bohr Institute. Furthermore, this statement is based on a teaching portfolio and reflection notes written by Dr. Pedersen.

Statement

Throughout the UP programme, Martin has developed his skills as a teacher by (intentionally and independently) working mainly on the following areas:

- Actively engaging the students (in online theoretical lectures)
- Implementing a flipped-classroom approach
- Increasing students' perception of the relevance of *Linear Algebra*
- Explaining abstract topics in a comprehensive way
- Changing students' focus from "solving problems at the exam" to deep understanding

First of all, it is important to stress that the Corona outbreak caught many lecturers at KU by surprise, since they had to change to online teaching abruptly. In this sense, it is impressive how quickly and effectively Martin adapted his teaching to the new format. In fact, Martin demonstrated full mastery of state-of-the-art IT tools for online teaching, in particular his synchronous writing on a virtual whiteboard was impeccable. Attending his online lectures was an extremely pleasant experience, one that did not feel so different from a presential lecture, due to Martin's technical and pedagogical expertise, not to mention his flawless time management.

The course was structured in a flipped-classroom approach. Students received materials beforehand and were expected to come prepared to class. These materials were of extremely high pedagogical quality. They included excellent (short) videos explaining key concepts, clearly formulated learning goals for each session, and exercises that would test whether or not these goals were achieved. All these sources made learning rather concrete and visible to the students.

In the lectures observed, Martin displayed an outstanding ability to explain complicated subjects in a comprehensive way. In particular, he made use of a broad repertoire of representations and analogies in his explanations so that students could make sense of the abstract mathematical topics that were being taught. It is noteworthy his capacity to assign physical/geometrical meaning to different parts of mathematical expressions, making the connections between mathematics and physics visible to students. Aware of the lack of interest of students who took previous editions of the course, Martin was constantly seeking to justify the importance of the topic (Linear Algebra) to their educational program. He often brought to his teaching examples that were both relevant to Nanoscience, and authentic from a research perspective.

During the block, Martin developed different strategies to face the challenge of interacting with students in an online environment. One successful example was the use of Padlet to pose conceptual questions for students to discuss in groups. This created an environment that made students co-responsible for the learning of the whole class, enabling Martin to get feedback on what they were mostly struggling with and adapt his teaching accordingly. Another example was the use of Socrative quizzes at the end of lectures, addressing important conceptual issues dealt in a particular teaching unit. The quizzes were very well formulated and pretty effective in making students aware of potential misunderstandings, motivating them to study specific topics more carefully.

From his reflection papers and our feedback sessions, it is clear that Martin invites open dialogue about his teaching and how it can be improved. He is open to constructive criticism and input, and he independently assesses what he would like to include in his didactical developments and what he will save for later use.

Summary

Based on the observations described above, we consider Assistant Professor Martin Cramer Pedersen to be an excellent teacher in higher education. He plans his teaching carefully and thoroughly. He is explorative in his teaching and uses his discoveries constructively to change and develop teaching in connection with planning, delivery and assessment.

Jesper Nygård
Niels Bohr Institute
Department Supervisor

Ricardo Karam
Department of Science Education
Educational Supervisor

KØBENHAVNS UNIVERSITET
UNIVERSITY OF COPENHAGEN

CERTIFICATE

This is to certify that

MARTIN CRAMER PEDERSEN

has successfully completed the course

Teaching and Learning in Higher Education
Universitetspædagogikum

2020

Hanne Andersen
Head of Department
Department of Science Education

FACULTY OF SCIENCE
UNIVERSITY OF COPENHAGEN

Course certificate

Martin Cramer Pedersen

Name

07-11-1985

Date of birth

Introduction to University Pedagogy Team 1 English Spoken

PhD course

5616-19-08-25

Course no.

3,00

ECTS

Henriette Tolstrup Holmegaard

Course Organiser

This course was offered by
the PhD School of SCIENCE,
University of Copenhagen.

15 November 2019

Final course date

Morten Pejrup
Head of the PhD School of SCIENCE

Evaluation of Martin Cramer Pedersen’s application for Associate Fellow at the Higher Education Academy (AFHEA)

Please refer to the Professional Standards Framework for details and explanations of the evaluation criteria: https://efs.weblogs.anu.edu.au/framework/

Areas of Activity

You have comprehensively demonstrated successful engagement in A3 and A4.

In response to A4, you’ve presented a thoroughly explained reflection on why the learning environment is important to encourage students’ learning in maths classes. I like the point you make about encouraging students to make mistakes - it makes me wonder whether there’s a potentially fun and interactive activity in giving students a set of incorrect solutions and getting them to deconstruct what went wrong and how to fix them. Perhaps this could tie in with the hints exercise you use - as a subsequent activity you could give students a selection of hints and ask them to identify which hints would be appropriate in the circumstance. Just a thought.

Core Knowledge

You clearly have a deep passion for mathematics and physics, and this shines through in your teaching. This interweaves with your passion for teaching, which is grounded in academic literature and acts as a basis for your continual evolution as an educator. I would encourage you to engage in some formal Professional Development at CHELT to further develop your capabilities as a teacher.

Professional Values

You are acutely cognizant of the wide range of different backgrounds, ability levels and interests within your student cohorts, and employ strategies to get the best out of every student.

The details in your reflection display your committed and respectful professional values – your point about Rutherford’s “impolite and sexist slight concerning barmaids' abilities for understanding physics” goes to show such professional values.

Overall

This is a beautifully written, thoughtful and inspiring application, thank you! You strongly demonstrate a commitment to reflective practice in thinking about how students learn, and how you can tailor your teaching to their needs. You demonstrate a deep sense of respect for students, and your responses to A3 and A4 show your passion for creating constructive, encouraging and valuable learning environments.

I enjoyed reading your teaching philosophy, and thought your point (drawing on Biggs) about how our role as educators is to help students to develop their declarative knowledge into functioning knowledge is really nicely articulated.

Coming from an Arts background myself, I was particularly fascinated to read your section on A3. It's interesting to see the dilemma that providing feedback in STEM subjects poses where, as you say, "solutions are usually easily categorised as right or wrong with little room for interpretation." It's particularly interesting because students in non-STEM fields often wish that the feedback could be more objective like in STEM subjects, whereas you're talking about how providing such direct feedback can be discouraging for STEM students! This just highlights how important it is to give constructive feedback to all students.

Similarly, your ideas about the role that feedback plays for both students and educators- that it's an evaluation tool in terms of our own teaching - encapsulated an issue that's often overlooked in course review processes. It was great to see how you addressed the challenges you faced in this area to change your approach to feedback as a tool to develop formative understanding. You also touch on the difficulty of scalable feedback for large classes like MOOCs. I'd be interested to know how you would approach this challenge, and what you're also going to do with your feedback strategies in future.

This is a wonderful application and a pleasure to read. I'm curious to see what you plan to do in future class activities and assessments, and I hope you can engage in teaching at ANU.

The Higher Education Academy

Certificate

This is to certify that

Martin Pedersen

has achieved the status of

Associate Fellow

of The Higher Education Academy

in recognition of attainment against the

UK Professional Standards Framework for

teaching and learning support in higher education.

Recognition reference:

PR118804

Date of recognition

05/12/2016

Professor Stephanie Marshall

Chief Executive

The Higher Education Academy

Professor Rama Thirunamachandran

Chairman of the Board of Directors

The Higher Education Academy Board