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The competence matrix as a tool to develop a PhD course with many teachers

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Background

A person receiving the PhD degree must have knowledge at the highest international level within their research field, master the scientific methodologies and tools, be able to analyse, evaluate and develop new ideas, to plan and carry out research and development tasks in complex and unpredictable contexts and to independently initiate research and development projects - to name but a few mentioned by The Danish National Qualifications Framework for Higher Education (ufm.dk). Naturally, PhD courses should be aligned with, support and build up these qualifications. PhD courses are therefore typically research-based courses on a high scientific level. To achieve such high academic level, a number of teachers with expert knowledge within specific areas are often involved. These can be from within the section, institute, faculty or university, but also from other universities in Denmark or abroad.

It can be difficult to efficiently develop and coordinate a PhD course with many teachers. There are many reasons for this. First of all, they might come from different teaching traditions. Further, the teachers will most likely already have teaching material from other courses, and there is no doubt they will be busy and will not have (much) time to think about or change teaching material to the course at hand. In addition, as each of the teachers brings an expert contribution on an isolated topic, the teachers might see their contributions as isolated entities and therefore might not feel overall course ownership. This can result in that they only consider the intended learning outcomes (Vlăsceanu et al., 2004) from their own teaching sessions and not how these are constructively aligned with the course ILOs and contributions from the other teachers. Further, the teachers might not be keen on spending time to develop and coordinate the PhD course with the course coordinators.

It can therefore be challenging for course coordinators to i) ensure that the involved teachers take active part in the planning process, ii) ensure that teachers feel responsibility and ownership of the course, iii) motivate teachers to develop and coordinate their teaching activities so that students achieve the ILOs and so that there is synergy, rather than repetition, between teaching sessions. Finally, to iv) structure continuous development of the course from year to year. Ultimately, if these goals are not achieved, the result can be a complex patchwork of misaligned contributions from the teachers, which can be frustrating to course coordinators, teachers and most importantly, the students. In this project, the use of a so-called 'competence matrix' is explored as a tool to reach these goals.

As her pedagogical project for the teacher development programme at the University of Copenhagen in 2008, Associate Professor Katrine Worsaae used a competence matrix to optimise the coordination and level of learning outcomes of a long-running MSc course in marine faunistics. This was a course that covered many subjects taught by a number of teachers. In her project, Worssae adjusted a competence matrix from Mogens Niss and Tomas Højgaard Jensen's use of a matrix-structure to relate mathematical subjects areas to the desired competences the students should get (Danish Ministry of Education, 2002, http://static.uvm.dk/). In doing so, Worssae created a competence matrix in which ILOs were ranked according to the so-called 'SOLO taxonomy' for each teaching activity. This visualized the contribution by individual subjects/teachers to the ILOs of the course and enabled constructive, fruitful and engaging discussions between the teachers. Further, it provided a tool for student evaluation. This project was published in the booklet 'Improving University Science Teaching and Learning Pedagogical Projects' by Christiansen et al., 2008. Competence matrices have also been used at the course level and the program level. In doing so, the matrices for the courses in a program are put together to form a program matrix. Examples can be found on the website of the CDIO (Conceive-Design-Implement-Operate) Initiative, which consists of a large number of educational institutions around the world working with education based on the CDIO framework (https://www.lith.liu.se/).

The aim of the present project is to explore a Woorsae's adjusted competence matrix in a new setting. Where Worsaae used it for adjustments of a long-running MSc course, in this project it is explored for the development of a new PhD course with teaching contributions from many specialist teachers. Thereby the intervention of this project is the use of a new tool to plan a PhD course.

The competence matrix to develop a new PhD course

The course

The course to be planned is a new PhD course in environmental DNA, eDNA. The course will be a five-day course, which will be offered by the Faculty of Health and Medical Sciences where it will be part of the Globe Institute's graduate programme. It will be offered once a year with 20-30 students from both Denmark and abroad.

The target group for the course is students that are in the beginning of their PhD, have little or no knowledge of eDNA, is about to embark on an eDNA project and are in need of overview in order to kick-start their projects. The ILOs of the PhD course are as follows: After the PhD course the students will be able to i) Describe each of the three main analytical workflows for eDNA analyses, ii) Argue for pros and cons of eDNA metabarcoding, iii) Design an eDNA metabarcoding project based on informed decisions re analytical workflow.

As such, the course will provide the students with an overview of the workflow when working with eDNA and enable them to tailor the analytical workflow to their particular research question. Topics will cover the different analytical workflows for eDNA analyses (qPCR, metabarcoding, shotgun sequencing) and challenges and limitations of the workflows with strong focus on metabarcoding. The students can then supplement this course with specialist courses within specific steps of the workflow, e.g. particular data processing methods for their analytical approach. The course will be passed based on active participation.

The two course coordinators will be the primary teachers on the course. In addition, there are nine other teachers, each contributing within their area of expertise. Together, the nine teachers will carry a large part of the teaching. The two course coordinators will teach the core eDNA topics and the nine teachers will add to this through specialist knowledge on specific topics and through case studies. The nine teachers will each teach for 1-3 hours within their field of expertise. Together, the nine teachers on the PhD course ensure that we achieve a high scientific level and research-based teaching.

The teaching activities will include lectures, exercises, group work and peer-feedback, experience with hands-on sample collection and a lab visit. Formative feedback will be provided throughout the course and after student activities. Further, throughout the course the students will use what they learn to continuously design and develop an eDNA research project. The continuous development of the research project is used to tie together the teaching sessions and enable the students to summarise, process and discuss what was learned during the teaching activities and ensure that they actively work with what they were taught. The course coordinators will be present at all times during the five days to facilitate overall organization, logistics and coherence.

The competence matrix to develop a PhD course

To begin the planning of the course, the course coordinators met to decide on the course's target group and overall learning outcomes. For each of these, a number of specific intended learning outcomes (ILOs) were specified. Further, a draft course program was made. Lastly, for each teaching session, the needed competences were assessed and the most suitable teacher was chosen and contacted for confirmation to teach on the course. Following the meeting between the course coordinators, a competence matrix was created to make a foundation for actively engaging the teachers in the course development. The competence matrix was based on the adjusted competence matrix by Worsaae (Christiansen et al., 2008) and had course ILOs as row headings and course days, subject areas and teachers as column headings (appendix A). Following Worsaae's recommendations, the competence matrix for the eDNA PhD course specified the ILOs and teaching activities as much as possible. After the competence matrix was created, the course coordinators met again and used it to make further adjustments to the ILOs and the course programme.

The draft course plan, the competence matrix and other course details were then added to a Google doc. In addition, a description of the SOLO taxonomy (Biggs & Collis, 2014) was added as explanatory text to the table. As in Worsaae (Christiansen et al., 2008), the competence matrix was then used as the foundation for a meeting between teachers. Due to COVID-19 restrictions, the meeting was in virtual form.

Before the meeting, the coordinators shared the Google sheet with the teachers and asked that they spent 10 minutes familiarising themselves with this document. Prior to the meeting, the coordinators ranked the ILOs for their own teaching sessions according to the SOLO taxonomy. That is, for each ILO they ranked the level they expect the students to have following their teaching sessions. This was done so that the coordinators would get familiar with the rankings and be free for discussions with the other teachers during the meeting.

The competence matrix as the basis for a meeting between teachers

The meeting was scheduled for 1 hour and 45 minutes, and the agenda for the meeting was: i) introduce the overall lines of the course, ii) discuss course learning outcomes and draft programme, iii) introduce the risks associated with planning a course with many teachers, iv) introduce the competence matrix as a tool for planning the course, v) teachers rank predicted learning levels of their teaching activities according to the SOLO taxonomy, vi) the course and the teacher contributions are further developed based on the rankings in the matrix, and vii) evaluation on the meeting and the use of a competence matrix to plan the course.

During point v) of the agenda, the teachers filled out the competence matrix. In the competence matrix, each teacher ranked his/her covering of ILOs and indicated the students' predicted learning levels according to the SOLO taxonomy (rank 1-5) (Biggs & Collis, 2014). The course coordinator's screen was then shared and the competence matrix and the course program formed the basis of the discussion. This created a time efficient, structured, engaging and focused discussion.

Based on the competence matrix, the following things were discussed in agenda point vi): Are there misalignments between ILOs and what is taught? Are any ILOs not covered by teaching sessions? Too covered? Should more or less emphasis on ILOs be included in individual teaching sessions? Should any teaching sessions be added or removed from the programme? Should the order of some teaching sessions be changed to ensure increased learning levels? How do we include more independent problem solving and exercises on the course? Should we adjust the length of any teaching sessions?

The outcome of the use of a competence matrix to develop a PhD course

The competence matrix visualized the contribution by individual subjects/teachers to the intended learning outcomes of the course and gave an excellent overview of coherence, progression of learning levels and any redundancies or topics not touched upon. It proved to be useful at two levels; to structure discussions between the course coordinators and to structure the meeting between all teachers. Between the course coordinators it formed the basis for a meeting and resulted in a rethink of the ILOs and a restructuring of content, teaching activities and programme.

At the meeting between all teachers, the competence matrix provided an overview of the course ILOs and how some of these were touched upon by several teachers and built up during the course, while other ILOs were concepts that needed a high level introduction in the beginning of the course that would then be drawn on in later teaching sessions. Yet other ILOs were almost solely depending on a single teacher. It offered a framework with which to concretely discuss course ILOs and align teacher contributions and highlighted topics not covered. It was time efficient and engaging to structure the discussions in this way, also because the meeting involved the activity of filling out the matrix. Further, it gave teachers ownership of the course development and knowledge that their contributions to the course are crucial. All teachers were enthusiastic and engaged in the discussions. Because it was easy for the teachers to get an overview of the course contents and ILOs, the competence matrix somewhat surprisingly served as a basis for idea generation, and the teachers contributed with many good ideas on teaching activities and how to further develop the course; on things that could be expanded and things that could be added. Some teachers even insisted on getting more time for teaching. Thereby, the competence matrix worked in creating engagement and ownership. Another benefit of the competence matrix was regarding alignment with a related PhD course. One of the teachers on the eDNA PhD course was developing a PhD course at the institute's graduate programme and here the matrix provided an overview for us to ensure alignment between the courses.

At the end of the meeting, the teachers were asked for their thoughts on the use of a competence matrix for planning the PhD course. They liked the overview that the matrix gave and agreed that it should be used for the further planning. Finally, the teachers requested that the next meeting was reduced from 1 hour 40 mins to 1 hour as we can skip the explanations of the matrix, ILOs and SOLO taxonomy because everyone is now on the same page regarding that. This shows that time efficiency is key to ensure engagement in planning a PhD project with many busy teachers who really want to engage, but need meetings to be efficient for them to do so. The fewer meetings and the least time that is booked, the more realistic it is that busy teachers will optimally participate. This makes the competence matrix an excellent tool in the planning process.

Now that we have the competence matrix as a tool for common understanding, we will include it in the further planning of the course to ensure the teachers continue to be engaged and feel ownership and to ensure that they align their teaching with the course ILOs and the other teachers' activities. The competence matric and the outcomes of the first meeting with the will now form the basis for discussions between the course coordinators and enable us to make final adjustment to the course programme. Following this, we will meet with the teachers and evaluate their predicted learning outcomes according to the final course programme and ILOs. This meeting will be more time efficient because course coordinators and teachers are now on the same page regarding the use of the competence matrix.

In this project, I used a competence matrix when planning a new PhD course with many teachers. But as shown by Worsaae (Christiansen et al., 2008), the matrix can also prove useful when adjusting existing courses. Therefore, we will further include the competence matrix in student course evaluation. Here, students will be asked to rank the ILOs they have acquired at each of the teaching activities. For simplicity, they will be asked to rank 1-5 and not according to the SOLO taxonomy. This will allow us to assess achievement of the ILO's and how teaching activities are aligned with the acquired competences. This will then form the basis for a meeting between all teachers to potentially adjust the course program and teaching activities prior to the second time the course is held. The course matrix will thereby be a tool not only for planning the course, but also for evaluating it, ultimately creating a common tool for all.

Conclusion

In this project, the adjusted competence matrix presented by Worsaae (Christiansen et al., 2008) was used as a tool for developing a new PhD course with many teachers. It proved to be useful at two levels: between the two course coordinators and at a meeting between all teachers where it formed the basis of constructive, engaging and efficient discussions. Here, it contributed to guide the teachers to make informed decisions on the contents of their teaching activities and give them insights into which ILOs should be covered by their teaching; what the students already know from previous teaching activities and what the students should know after their teaching activities. This will ultimately enhance consistency between teaching activities and coherence throughout the course. Further, the competence matrix contributed to idea generation of engaging teaching activities. Finally, it gave us a tool to work with for student evaluations and continuous adjustment of the course from year to year.

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Table 1. Competence matrix. In the competence matrix, each teacher has ranked their teaching for the course intended learning outcomes, ILOs, according to the SOLO taxonomy (rank 1-5, 1 lowest, 5 highest learning level, N/A if not applicable). The rankings reflects the level the teacher expects the students to have after the teaching session. Intended Learning Outcomes (ILOs) define what a learner will have acquired and will be able to do upon successfully completing the course.
Level 1: Prestructural - no understanding, the student has no knowledge of the area, at this level the learner is missing the point. Quantitative level.
Level 2: Unistructural - first level of understanding, students can repeat terminology, individual structure and self-contained concepts. Students can identify, name, define, mark. Quantitative level.
Level 3: Multistructural - students can repeat more terms, structures and concepts within the same subject and in greater detail than in level 2, students can narrate something, re both numbers, illustrations and/or descriptions. Students can define, describe, enumerate. Quantitative level.
Level 4: Relational understanding - students demonstrate coherent understanding by integrating facts, concepts and theories in a structure and applying concepts to a set of data or a problem. The students can relate, analyse, apply. Qualitative level.
Level 5: Extended abstract understanding - the student can go beyond the concrete and move into other subjects, question what is known and eventually construct new knowledge. The students can discuss, evaluate, create. Qualitative level. (Biggs & Collis 1982, adopted by Rienecker, Jørgensen, Dolin & Ingerslev 2019)

In the table, CC1 and CC2 = course coordinators, T1-T9 = teachers.

	Teaching days																
	Topics & teachers																
	Monday				**Tuesday**				**Wednesday**					**Thursday**			**Friday and all other days**
Intended learning outcomes, ILOs	Overview eDNA (CC1)	Overview of 3 workflows (CC2)	PCR (CC1)	qPCR (T1)	(a)eDNA & metabarcoding (F2)	(a)eDNA shotgun seq (T3)	Seq technologies (T4)	Sample collection theory (CC1)	Collect water samples (T8, T9)	Metabar lab workflows (CC2)	qPCR in metabarcoding (CC2)	Metabar decisions (T5)	DNA extraction (T6)	Data process (T7)	Filtering data (CC1)	Lectures on applied projects	Course project
The three main analytical workflows for eDNA analysis																	
ILO1: Outline considerations for sampling/study design	n/a	1	1	1	2	2	2	2-3	2	n/a	n/a	3	2	n/a	2	2	4

ILO2: Outline considerations for sample collection	n/a	1	1	1	2	4	n/a	3-4	3	n/a	n/a	1	2	n/a	n/a	2	4
ILO3: Demonstrate an understanding of DNA extraction protocols in eDNA studies	n/a	n/a	2	n/a	n/a	3	2	1-2	1	n/a	1	2	4	n/a	n/a	2	3
ILO4: Describe PCR amplification	1	1	4-5	2	n/a	n/a	2	n/a	1	n/a	2	1	n/a	n/a	n/a	n/a	2
ILO5: Outline the eDNA qPCR analytical workflow	1	2	n/a	4	n/a	3	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	2	n/a
ILO6: Describe the metabarcoding analytical workflow	1	2	n/a	1	3	n/a	n/a	n/a	n/a	4	4	3	n/a	3	4	2	4
ILO7: Outline the shotgun seq analytical workflow	1	2	n/a	n/a	2	2	3	n/a	n/a	n/a	n/a	3	n/a	3	n/a	2	n/a
ILO8: Outline Illumina Next Gen Seq for eDNA	1	1	n/a	n/a	n/a	2	3	n/a	n/a	2	n/a	1	n/a	3	2	1	4
Pros and cons of eDNA metabarcoding																	
ILO9: Outline the contrast of metabarcoding to qPCR in eDNA studies	1	2	n/a	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	3	1
ILO10: Outline the contrast of metabarcoding to	1	2	n/a	n/a	4	4	3	n/a	n/a	n/a	n/a	1	n/a	3	n/a	3	1

shotgun seq in eDNA studies																	
ILO11: Describe the pros and cons of metabarcoding in eDNA studies	n/a	1	n/a	n/a	3	n/a	n/a	n/a	n/a	3	3	3	n/a	2	2	3	4
ILO12: Describe measures to ensure optimal lab set-ups for metabarcoding studies	n/a	n/a	n/a	n/a	4	n/a	3	2	n/a	4	4	4	4	n/a	2	3	4
ILO13: Describe steps in data processing in metabarcoding studies	1	1	n/a	n/a	3	n/a	n/a	n/a	n/a	1	1	3	n/a	3-4	2-3	3	4
Design an eDNA metabarcoding project based on informed decisions re analytical workflow																	
ILO14: Outline applications of eDNA studies	2	1	n/a	3	4	4	n/a	2	2	1	1	1	n/a	n/a	1-2	3	4
ILO15: Discuss and evaluate the effect of different metabarcoding strategies.	n/a	1	n/a	n/a	2	n/a	2	3	n/a	4	n/a	4	n/a	2	2	3	4
ILO16: Formulate an effective and informed strategy for a metabarcoding study	1	1	1	n/a	2	2	n/a	2-3	2	4	4	4	4	2	2-3	3	5