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# **Development of a new course on analysis methods in cognitive neuroscience using problem-based learning**

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## **Introduction**

The aim of this essay is to give a basic overview of problem-based learning as a teaching/learning activity, and to develop a suggested example syllabus for a new course of methods, to be integrated into the Behavioral Neuroscience master program at the Institute for Biological and Medical Psychology (IBMP). In a recent review of the master program by the committee of which I was a member a reorganization of the master programs in psychology faculty was recommended. Internally within IBMP, a stronger weight on developing the competence within methods of cognitive neuroscience has been long discussed as a central point in the development of the curriculum. However, devising a successful and sustainable new study module requires careful consideration, in order put the resources of the faculty to most efficient use and ensure that the students emerge from the module ready to put the knowledge into action both for their thesis project as well as in their future career. In this essay I review problem-based learning as an instruction technique and demonstrate how this can be applied on a methods course in cognitive neuroscience.

## **Demands on the teaching of methods**

The fields of psychology and cognitive neuroscience have always required the student to have aptitude for statistical and data analysis methods, and the ability to develop new skills rapidly. Even the design and analysis of simple behavioral tasks for a first course project requires the application of novel concepts and approaches, learning to use new and often quite non-intuitive software, and applying the knowledge one has been presented in the form of ideal textbook cases to the (often quite messy) real world. Worse yet, the problems one encounters in analyzing experimental data may be open-ended, of the type to which many analysis methods may suit, without any one of them being the single “correct” one. In the applied psychology program (*profesjonsstudie*) the main consideration is preparing the students for the day-to-day work as a psychologist, requiring the knowledge of psychological and psychiatric symptoms and intervention approaches. The scientific method courses in the applied psychology program therefore should give the students a firm grounding in the experimental methods to enable the future practitioner to be the discerning consumer of

scientific literature in his or her field of specialization. By contrast, the bachelor and master track of psychology studies prepares the students for, among other career paths, that of a scientist. Correspondingly, the teaching of the methods should not only enable the student to gain an understanding of scientific literature, but arm the student to choose a suitable approach to the data from amongst a wide array of possible analysis approaches, and defend the choice as the best suitable, while showing awareness and consideration of other possibilities. This requires more than giving the students a set range of information to acquire. Instead, what must happen is what Biggs (1999) calls *conceptual change*: changing the perception of data analysis from a set mathematical problem to which there is a single correct answer to a process where multiple decisions must be made, each having a certain range of confidence associated to these, and acknowledging that the final answer is limited by these insecurities – but yet being able to interpret the answer in its appropriate scientific context.

### **Problem-based learning for constructive alignment**

Teaching the analysis methods is not possible with a pure lecture approach, as the students do not have the chance to apply what they have heard. Instead, the course needs to integrate student activities in the goal of achieving this conceptual change. The idea of *constructive alignment* (Biggs, 1999) between what the student is expected to demonstrate and how the course should be constructed suggests that the curriculum should match the learning objectives and the teaching methods as well as assessment approaches.

A teaching activity which has a high level of constructive alignment is problem-based learning. Problem-based learning technique originates from medical education, where there is a clear need for the courses to turn out individuals who are as close as possible to independent practitioners. Introduced in the 1970s at a single medical school in USA to address the pain of transitioning from a student to a clinician (Barrows, 1996), it has by now spread to various other fields worldwide (Hung, Jonassen, & Liu, 2008). Problem-based learning has the following core model (Barrows, 1996):

- Learning is student-centered, with students taking the responsibility for the learning and seeking the information that they need to address the issues they identify;
- Students are gathered into small groups, which are rotated between courses;
- Tutors are facilitators, not lecturers; their role is to offer the metacognitive skills for students to effectively guide their own learning;

- Learning is focused on problems which need to be solved (e.g., clinical case studies);
- Problems should match the “real world”, in that the student is given a starting point, around which he or she can inquire and gather information;
- New information is obtained by self-guided learning.

Problem-based learning as a philosophy has, of course, a long history. The 19<sup>th</sup>-century Baltic-German scientist, pioneer of embryology K.E. von Baer recounts in his memoirs (von Baer, 1866) how as a young man he journeyed to a university town in Germany to take courses in comparative anatomy with a famous professor. Having timidly knocked and entered the rooms, he hears with dismay that the professor does not give lectures on this semester. Disheartened, he turns to leave the room - and the town – when he hears the professor call out: “But what do you need the lectures for? Find some animal, bring it here and dissect it.” Thus the following morning the young von Baer turned up in the study with a leech obtained from a local pharmacy, and the rest is medical history.

Is problem-based learning effective? And what conditions must be satisfied for this to work? Barrows (1996) makes the point that for efficient learning, the entire curriculum must be problem-based, allowing for knowledge to be integrated across various fields. The basic unit of instruction is the problem, thus a set of problems must be assembled that, when they are solved, have covered the material the student is expected to cover. The list of problems for the course also includes the list of learning objectives, which should rather be a guideline to the tutors, not to the students. Barrows suggests a matrix-based approach as a tool to translate a “traditional” curriculum to a problem-based one, where the rows represent the subject areas, and the column headers represent problems, giving an overview which additional problems need to be devised for the subject areas to be covered. The problem-based learning turns the “traditional” curriculum on the head: instead of working one’s way up from the basic principles and then applying these in the end of the course on a problem, one is given the problem in the beginning of the course, and the rest of the time is spent on acquiring the skills and knowledge to solve this problem (Hung et al., 2008).

A concern for both students and educators is whether problem-based learning results in the “basics” being acquired in a solid fashion: are the students acquiring the basic principles of the material? Studies comparing problem-based learning and traditional learning have found mixed results, with meta-analyses suggesting that problem-based learning may result in lower performance of knowledge-based tests, even as it leads to better acquisition of “real-life” skills and ability to apply them in new situations (Hung et al., 2008). However, there are

several studies showing that the problem-based learning increases the performance also in “traditional” tests, or at least does not result in underperforming. For example, psychiatry students following a problem-based curriculum received significantly higher scores in multiple-choice tests (McParland, Noble, & Livingston, 2004).

### **Designing the problem**

A central question, of course, is: how should the problem be designed? Effective problem can be defined as one where there is a high correlation between the learning issues that the students generate, and the objectives that the course designer has listed (Dolmans, Gijsselaers, Schmidt, & Van Der Meer, 1993). Dolmans and colleagues provide a cautioning statistic from a series of empirical studies showing that there was, on average, 64 % of overlap between the learning objectives identified by the tutors and those by the students. While the students would have set up learning issues the tutor did not foresee, they would nonetheless have missed the issues intended by the tutor – these are two distinct types of mismatch between the students and the tutor (Dolmans et al., 1993). Dolmans and colleagues recommend that, to maximize the overlap, problems should:

- Match the levels of previously acquired knowledge;
- Be concretely formulated and brief;
- Refer to students’ future professions.

Hung (2006) provides a conceptual framework for problem design, consisting of core components (*content, context* and *connection*) and processing components (*researching, reasoning, and reflecting*). The core components support the learning of concepts, whereas processing components relate to metacognitive abilities: learning and problem solving skills. Regarding the *content* acquisition, one considerable concern is the design of the problems in a way that it lures the students to process large amount of information that is not directly related to the central content, leading to failure to concentrate on the underlying basic knowledge. To avoid this, the problem design should in fact be quite preoccupied indeed with the intended learning objectives. On the other hand, the problem needs to be complex enough to develop deep learning as opposed to surface learning (Hung, 2006). To support the *context* portion of the core components, the problem should be as life-like as possible, thereby promoting the transfer of the knowledge in future occasions. Also, there should be high contextual validity: the context of the problem should be the context which the student is likely to encounter in the

professional future. Finally, *connection* refers to the organization of the learning in sets of interconnected problems, where the concepts within the problems partially overlap, to allow integration of the knowledge across a wider field. The processing components refer to the students' ability to construct the problem space (including specifying a goal state), as well as various metacognitive abilities.

Studies examining students' perceptions of problem-based learning courses have found that students experience anxiety about self-guided learning in particular regarding how they are evaluated (Jost, 1997), however the dissatisfaction is reduced over time within the teaching module once the students get comfortable with the teaching style and their new role as active participants in the learning (Hung et al., 2008).

### **Designing a methodological course following the problem-based learning approach**

Given the considerations above, how can we put this knowledge into use in designing a course in the methods of cognitive neuroscience for master students? The central question is: what are the abilities that the students need to develop?

The requirements for the students who follow the Behavioral Neuroscience master program at the IBMP include a master thesis of 60 credits (*studiepoeng*). The completed degree qualifies the students for doctoral studies and other research in psychology, as well as various types of work requiring «*informasjonskompetanse, kritisk tenking, formidling og evna til å arbeide både sjølvstendig og i team*» (<http://www.uib.no/studieprogram/MAPS-PSYK/PSYKNEVRO>). For the master thesis, the student is connected to one of the research groups within IBMP, carrying out the research and writing the thesis in the second year of the master programme. The Behavioral Neuroscience master thesis differs from the other master programs in the Faculty of Psychology in that the student is likely to gather or analyze biological data from human or non-human animals, which brings with it some specific considerations: data gathering and analysis often requires the integration of multiple, specialized (i.e., non-consumer-friendly) hardware and software components. While the specific details of the components involved differ between the research groups and projects, there are many transferrable skills, such as manipulating complicated data structures. Correspondingly, a methods course should give the students the metacognitive skills to find solutions to problems arising in a laboratory work. This relates to the *processing* components

of the Hung's framework summarized above, in particular the ability to efficiently construct a problem space in response to an ill-specified problem.

Appendix presents a draft of a syllabus which I designed, used in the internal discussions within IBMP as a starting point for the development of the module. How can the learning goals presented in this draft be reached using problem-based learning? Can we construct a set of efficient problems which would guarantee that the students, in self-directed learning, would generate learning issues with maximal overlap with the learning goals set by the faculty?

As summarized above, one of the recommendations by Dolmans *et al.*, (1993) is that a good problem should match the levels of previously acquired knowledge. As the intended module would be presented in the second semester of the master studies, the students would have already acquired two important blocks of knowledge: familiarization with the basic principles of neuroimaging (including laboratory demonstration) and statistical methods course. The students may also have varying levels of previous experience with neuroimaging work via their course projects from bachelor degree. However, in these projects the students would rarely be exposed to the “kitchen side” of the project, and rather work with data gathering and analysis in a situation where the integration and preprocessing has already been completed. This module, therefore, aims to take the students exactly to the point where they can apply the theoretical knowledge and limited hands-on experience and become the “owners” of a research project.

In the following text I present and discuss four example problems which would form the core of the course, covering the learning goals presented in the “traditional” syllabus (see Appendix).

## **Example problems**

### **Problem 1**

*Event-related potentials are used to find out if brain processes different stimulus types (such as faces and non-faces) differently. In analysis, the short segments of EEG data containing the stimuli are cut out and averaged separately. How can we cut the EEG data precisely around the stimuli, and sort these cut segments depending on the stimulus they contained?*

This problem takes the theoretical knowledge which the students have acquired during the neuroimaging lectures (event-related potentials and signal averaging, demonstration of the

EEG recording involving a stimulation computer and a recording computer) and presents this as a problem aimed at the following learning goals in the syllabus:

- Understanding of technical components of a behavioral neuroscience experiment (knowledge)
- Overview of commonly used software for stimulus presentation and data analysis (knowledge)
- Preparation of experiment using a presentation software (skills)
- Transferring an experiment from behavioral to psychophysiological setting (synchronization and triggering) (skills)
- Understanding of laboratory procedures in EEG and MRI laboratory settings (general competence)
- Ability to reflect about the consequences of methodological choices during preparation of an experiment (general competence)

The learning issues that the students should generate during the initial structuring of the problem space should (in the optimistic hopes of the tutor) relate to finding out the following:

- How are the segments defined in the recorded EEG file? (The concept of markers, and the very central methodological issue of synchronization between stimuli and brain responses)
- What options are there in the stimulus presentation software to signal that a stimulus is being presented? (Stimulus presentation, triggering, coding the trigger signals for two different stimulus types)
- How can the different computers actually communicate with each other to send the signals? (Data ports)

The following independent work before the next meeting should be aimed at finding the answers to these questions. The students will divide the learning issues within the group. At the next meeting, the students should aim to put this knowledge to test in the laboratory by setting up the appropriate marker signals and recording dummy EEG data to see whether the markers are stored in the file.

## Problem 2

*There is a small program written in Matlab programming language (provided by the tutor) which can rapidly tell you at which timepoint the subject's brain first notices a difference between face and non-face stimuli. This program can only process EEG data file when it is in*



*the Matlab .mat data file format. How can you take EEG data recorded with Brain Vision Analyzer and turn it into Matlab-readable data files?*

This addresses the following goals:

- Overview of commonly used software for stimulus presentation and data analysis (knowledge)
- Data manipulation using Matlab environment (skills)

There is an overlap between the learning goals that this problem and the first problem address, as recommended by Hung (2006). Under this problem, the students are expected to generate the following learning issues:

- What is Matlab? How can one run programs written in Matlab? (Basic familiarity with the Matlab environment)
- Is there any way that Brain Vision Analyzer and Matlab can be made to communicate with each other? (Data export from Brain Vision Analyzer)

At the following meeting, the students should test out the export of a data file from Brain Vision Analyzer and running the Matlab-based program on this data file.

### Problem 3

*Of these two EEG datasets one was acquired in a room that had many plugged-in electrical devices near the subject. Find out which of the datasets it was.*

This addresses the following goals:

- Understanding of technical components of a behavioral neuroscience experiment (knowledge)
- Ability to reflect about the consequences of methodological choices during preparation of an experiment (general competence)
- Understanding of laboratory procedures in EEG laboratory settings (general competence)

For this problem, the learning issues the students would generate should involve the following:

- What are the characteristics of electrical noise artefacts in EEG data?
- How can we detect this in a dataset? (Frequency analysis, filtering)

## Problem 4

*This EEG dataset comes from a patient is suspected of having prosopagnosia. The patient was shown face and non-face stimuli. We know that there is typically a significantly stronger negativity at 170 ms in the occipital electrodes for face compared to non-face stimuli. How can we tell the neurologist whether this dataset supports the prosopagnosia diagnosis?*

This addresses the following goals:

- Statistical analysis of EEG data
- Visualization and communication of EEG results

For this problem, the learning issues the students would generate should involve the following:

- What kinds of statistical tests are appropriate on the ERPs?
- How can we perform these tests on a subset of electrodes in a certain time window?
- What is an appropriate format for communicating results from an EEG study?

## Summary

In this essay I have taken a draft of a course syllabus designed in a “traditional” structure, with lectures and lab exercises, and repurposed this into a problem-based learning course, consisting of four major problems covering the same learning goals as the traditional one. While this has not been put to use yet, this re-organization will form the basis of discussion for the new curriculum in IBMP. One weakness in designing the problems I strongly noticed was my lack of experience: it is difficult to predict how large the overlap between student-generated learning issues and my intentions would be. In previous experiences of student-led teaching and learning activities there would always have been unexpected directions which I would note and take into account the next time when using the same activity. Piloting and a careful analysis of the problems, as recommended by Hung (2006) will be necessary. However, in considering the ways to transform the course I am certain that introducing problem-based learning will lead to favourable outcomes.

## References

- Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New directions for teaching and learning*, 1996(68), 3-12.
- Biggs, J. (1999). What the student does: teaching for enhanced learning. *Higher education research & development*, 18(1), 57-75.
- Dolmans, D. H., Gijssels, W. H., Schmidt, H. G., & Van Der Meer, S. B. (1993). Problem effectiveness in a course using problem-based learning. *Academic Medicine*, 68(3), 207-213.
- Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. *Interdisciplinary Journal of Problem-based Learning*, 1(1), 6.
- Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. *Handbook of research on educational communications and technology*, 3, 485-506.
- Jost, K. L. (1997). A Study of Problem-Based Learning in a Graduate Education Classroom.
- McParland, M., Noble, L. M., & Livingston, G. (2004). The effectiveness of problem-based learning compared to traditional teaching in undergraduate psychiatry. *Medical education*, 38(8), 859-867.
- von Baer, K. E. (1866). *Nachrichten über Leben und Schriften des Herrn Geheimraths Dr. Karl Ernst von Baer, mitgetheilt von ihm selbst ; veröffentlicht von der Ritterschaft Ehstlands*. St. Petersburg: Schmitzdorff.

## **Appendix. Methods in behavioral neuroscience** (15 ECTS – can be adjusted!)

### **1. Content**

The course gives training in research methods, with focus on preparing, conducting and analyzing EEG experiments, and communicating the results in visual and written format.

### **2. Undervisningsformer** (lectures, seminars, lab exercises), total number of hours (XX – to be adjusted)

Lectures

Lab exercises

### **3. Obligatory activities**

Attendance in the lectures, as well as participation in the lab exercise group.

### **4. Læringsutbytte**

#### a) Knowledge

- Understanding of technical components of a behavioral neuroscience experiment
- Overview of commonly used software for stimulus presentation and data analysis

#### b) Skills

- Preparation of experiment using a presentation software
- Transferring an experiment from behavioral to psychophysiological setting (synchronization and triggering)
- Data manipulation using Matlab environment
- Statistical analysis of EEG data
- Visualization and communication of EEG results

#### c) General competence

- Ability to reflect about the consequences of methodological choices during preparation of an experiment
- Understanding of laboratory procedures in EEG laboratory settings

### **5. Examination**

Ongoing assessment (completion of lab exercises)

Home exam (written paper)