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Implementing a student-centered exercise format in a PhD course in applied biostatistics

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Introduction

Statistics is widely taught in different educations and levels due to its instrumental role in other disciplines and its role in the development of critical thinking (Batanero, 2004). Despite the fact that most university students in science take at least one course in statistics during their education, statistics continuously seems to be a "foreign language" for many students who never obtain the associated competences. Although many students may be capable of manipulating formulas and equations, they do not have the ability to understand what statistical procedure to apply when facing a real data set (Quilici et al., 1996).

Good teaching is teaching that makes it possible for all students to make progress. Accordingly, teaching should preferably be tailored to each individual student (Splittorff et al., 2009). The challenge is to reach students at all levels. One way of doing this could be to differentiate exercises, to avoid that the tasks become too hard for some but still offer a challenge in order for each individual student to learn.

Part of learning is relating what is taught to what is already known (Illeris, 2003). The teacher's job is to help provide the link between the two. One way to do this is to put the methodology taught into a well-known context for instance through example based exercises (Quilici et al., 1996). In the context of statistics, this may be done using data examples from the literature within the research area of focus to the students.

Interest and mobilization of mental energy affects the students' attitudes to the intended learning (Illeris, 2003). It is therefore beneficial to the learning process if case studies and exercises appeal to the individual student. In courses teaching cross-field disciplines, i.e. a PhD course in biostatistics, students may come with very diverse backgrounds and interests. In such a course, providing examples that appeal to all is a challenge.

Differentiated instructions are well-used and examined in elementary school, but very few studies have been made in adult learning, even though adult students are perhaps even more diverse due to varying educational and life experiences (Dosch et al., 2014). From the few studies performed at college level a common outcome is the students appreciation of having choices and that this allowed them to learn better (Dosch et al., 2014). Additionally a few studies have found a significant increase in the final score for the students taught using differentiated learning compared to the traditional teacher-centered learning (Chamberlin et al., 2010; Dosch et al., 2014).

The present project implements a student-centered exercise format in the PhD course: *Applied biostatistics in biological sciences using **R** with focus on applications in nutrition, physiology, and plant and environmental sciences.* The new format includes choice of exercises based on examples from two different main areas, 1) nutrition and physiology and 2) plant and environmental sciences, as well as two levels of details provided in the exercises.

Methods

The course

*Applied biostatistics in biological sciences using **R** with focus on applications in nutrition, physiology, and plant and environmental sciences* is a relatively new course, as 2017 was the first time we ran the course. The overall aim of the course is to give PhD students in applied biosciences a solid ground for analyzing and interpreting their own data.

The course is an intense one-week course with lectures and exercises followed by three weeks to write a report on the PhD student's own data. The lectures include theory but are primarily based on examples and hands-on instructions on how to do the appropriate analyses in the statistical programming software **R**. The assessment of the course is an evaluation of the report assessed with passed/not passed. The students additionally get feedback on what to improve to pass, if not passed in the first attempt, or in general to improve the analyses and presentation.

There are no specific prerequisites for the course in terms of other courses, but there is an expectation that the students know the basic statistics.

The intended learning outcomes for the course is:

Skills

- To understand key concepts and ideas underlying a wide range of statistical methods
- To interpret output and results from a wide range of statistical analyses

Competences

- To identify and apply appropriate **R** functionality for data analysis and visualization
- To define statistical challenges for given data sets and limitations in the introduced statistical methodology

The students

Twenty-eight PhD students participated in the course in 2018. The class consisted of PhD students with a very diverse geographical background, counting students from North America, Asia and Europe, including 12 PhD students with a Danish background. Most, but not all, were in a current PhD position at a Danish University. The PhD students were involved in wide range of research areas including bioengineering, agronomy, biology, nutrition and physiology.

The level of the PhD students in terms of statistical background knowledge and experience with the software used ranged from low to relatively high, as judged by activity during lectures and performance in exercises. The big majority had one or more statistics courses “in their backpack”, but for many of the participants the methods taught were well hidden or long forgotten or never grasped.

Student-centered exercises

Two changes to the exercises were tested this year:

1) Within each exercise session covering a specific topic, a range of exercises from different research areas were provided. All exercises were constructed in a way that to a certain degree the same skills and competences were trained in all exercises.

2) All exercises were provided in two versions. Version A of an exercise included a description of the data example and one or two research questions providing an open-ended exercise for experienced students. Version B additionally included a step-by-step guide on how to answer the research question providing more help for those in need of it, but without giving away all the details.

Starting each exercise session, the PhD students were told to choose freely between all exercises finding an exercise that they found interesting and perhaps even related to their own research area. Furthermore, the PhD students were encouraged to start out in version A of the chosen exercise and only move to version B if they were stuck. Each time an exercise session started the PhD students were encouraged to spend a little extra time in version A, compared to the last session, before moving to version B of the exercise. Two teachers were available for help and discussion during all exercise sessions. In last exercise session, the students were encouraged to team up with someone interested in the same type of assignment.

Evaluation of the new format

Evaluation of the new format of exercises were based on oral evaluation in plenum and an anonymous questionnaire focusing on the new format of exercises sent to all participants at the course 2 weeks after the final course day.

Statistical analysis

Questions from the questionnaire with only two possible answers (Yes/No) were analyzed using logistic regression and results were reported as percentage with 95%-confidence intervals.

Time spend on the two different versions of the exercises were summarized to whether or not there was an increase in percentage time spend on version A of the exercises from the first exercise session to the last.

Results

All course participants took active part in the plenum evaluation of the course and seventeen course participants answered the online questionnaire. The outcome from the questionnaire and the oral evaluation is presented below for the two changes separately.

Using example data from several research areas

Of the 17 answering the questionnaire, 88.2% (67.9-97.9) liked the use of exercises inspired by data from different research areas. One person elaborated this by saying "This was a very interesting part of the course for me".

When asked whether they understand the statistical challenges better if exercises are based on data close to their own research area 82.3% (60.4-95.3) answered yes. One elaborated this with saying: "I will be more motivated if the data set related to my research area", while one person disagreeing explains his/her answer by saying: "I think that it is very useful to understand statistical challenges also if they are a bit far from your own research area, and as long the design of the experiment is explained, it is okay".

Finally, 94.1% (76.6-99.6) stated that we as teachers succeeded in presenting exercises that appeal to him/her.

Two levels of detail

All 17 of the 17 answering the online questionnaire liked the use of version A and B for the exercises. One participant elaborated his/her answer saying: "Very nice to start without help - and then move on. If we only had version A, I think we would have waited for help instead of figuring out ourselves". Another wrote: "I thought I gained most from sticking to version A and asking for help. But thinking back it might have been the wrong approach caused by my stubbornness. I think some of my questions could have been found in the version Bs", while a third participant elaborated the answer with: "I did not use it that much myself, but I think that it will be more helpful for the ones that had more challenges with the statistical exercises".

Of the 17 answering the online questionnaire, 1 did not provide time spend on the two versions, 8 spend less time, 4 spend the same amount of time and 4 spend more time on version A on the last day than on the first day.

Finally, the students were presented with the main purpose of running the exercises in two versions: To give all participants the opportunity to train the following competences: 1) To be able to identify statistical challenges for given sets. 2) To be able to identify which model is appropriate for given data sets. When asked whether they felt these goals were achieved, no one answered "No", 58.8% (35.4-79.7) answered "Yes" and 41.2% (20.3-64.6) answered "To some degree".

Discussion

Overall, the new format of exercises was a success and an improvement over the existing format of the exercises and I take notice that all students appreciate the two levels format of the exercises.

Based on my impression from the exercises sessions, I was expecting that most students spend an increased percentage of time in version A of the exercises on the last day compared to the first day. However, this was not the case. There may be several reasons why this was not the case, one being that the level of the theory introduced in the lectures and subsequently trained in the exercises were much higher on the last days than in the beginning of the week where the material covered was repetition for a big part of the PhD students. For many of the PhD students the content of the last days of the course was associated with understanding or at least accepting a considerably new way of thinking of experiments and the resulting challenges in terms of data analysis and this transcendent learning was not achieved by everybody, at least no during the course (Illeris, 2003).

Another reason may be the limited time and number of exercise sessions the participants had to get used to the format. While the format is supposed to gradually build up the competences to identify statistical challenges and appropriate model for a given data set, a competence in the definition as the ability to perform adequately and flexibly in well-known as well as unknown situations takes time (Illeris, 2003). In that matter, the format may be even more suited for courses that takes place over a longer period, i.e. block or semester courses, for the students to have more time to get familiar with the exercise format.

The use of the two versions of exercises were supposed to make the PhD students take responsibility for their own learning. Taking responsibility for own learning should in general be expected for PhD students, however, statistics as a discipline is not the main interest for the participants on this course coming from applied research areas.

The use of teams in the last exercise session gave a boost to the format from my point of view. Most teams really used each other for competent peer feedback on ideas on how to solve the exercises, trying of ideas on each other before they asked one of the teachers, which again gave them more faith in their own solutions (Rienecker et al., 2015; The University of Edinburgh n.d.). The sparring gave everybody a lift that made the teachers redundant for a longer time. This again made it possible for us to take notice of the different ways of approaching the exercises and facilitating the discussions going on rather than just being problem solvers.

Conversations with students at bachelor and master level often reveal that they feel unfamiliar with the data examples used in the basic statistics courses and that this makes it harder for them to understand the methods taught and to see how it fits into their own study field. The examples used in the student-centered exercises were chosen from the literature with the purpose of reflecting fundamental principles and ways of thinking that could be generalized for many research disciplines (Mørcke et al., 2015). To promote thinking by analogy, providing examples close to the field of interest/research of the student may ease the recognition of similar problems, in order to map the method, which in the end hopefully leads to abstraction (Quilici et al., 1996).

Perspectives

The student-centered exercise format has potential and could be further developed for the course next year. In particular, I would expect a deeper introduction to the format and how it fits into the learning outcomes of the course would benefit the outcome (Jørgensen, 2015). Teamwork will be encouraged from day one.

A third version of the exercises may additionally be introduced; a step-by-step solution on how to do the programming to get through the exercises. Students struggling with the programing part could use this version to avoid spending too much time on this part but instead having more time to focus on the interpretation of the results. Finally, the format should be implemented into other courses, particularly courses involving more exercise sessions.

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A Examples of exercises

This appendix contains examples of two exercises from different research areas used at the PhD course in 2018. Both exercises are provided in a version A and a version B.

Exercise 1 version A

Three standard cultivars (st, ci, wa) and 30 entries was laid out with 6 blocks (Pattersen, 1994). Only the three standards were repeated among the blocks; the other 30 cultivars were only observed once.

Data are available in the file: augmented.xlsx

Answer the following research questions:

1) What is the estimated mean yield for each cultivar?
2) Which cultivar(s) is the best in terms of highest yield?

Exercise 2 version A

Relaxation techniques could lower the heart rate. In a randomized trial 28 recreational distance runners were randomly allocated to one of 3 treatments: control, meditation, or progressive muscular relaxation (PMR). The steady state heart rate during a standardized running test was taken before and after a two-week treatment period (Ashley *et al.*, 1996).

Data are available in the file: RELAXATION.CSV

Answer the following research question:

1) Did any of the two relaxation techniques lower heart rate as compared to the control?

Exercise 1 version B

An augmented design with three standard cultivars (st, ci, wa) and 30 entries was laid out with 6 blocks (Pattersen, 1994). Only the three standards were repeated among the blocks; the other 30 cultivars were only observed once.

Data are available in the file: augmented.xlsx

Answer the following research questions:

1) What is the estimated mean yield for each cultivar? To answer this question proceed through the following steps:
    a. Import the data and make sure that the import was successful
    b. What is the random effects structure based on the experimental design?
    c. Fit a linear mixed model using the random effects structure found above (Hint: Use *lmer()* from *lme4*)
    d. From the fitted model obtain estimated means and standard errors for each cultivar

2) Which cultivar(s) is the best in terms of highest yield? To answer this question proceed through the following steps:
    a. Compare estimated yields between cultivars (Hint: use *glht()* in *multcomp*)
    b. Does the highest yielding cultivar differ significantly from all other cultivars or are there any other cultivars that performs equally good

Exercise 2 version B

Relaxation techniques could lower the heart rate. In a randomized trial 28 recreational distance runners were randomly allocated to one of 3 treatments: control, meditation, or progressive muscular relaxation (PMR). The steady state heart rate during a standardized running test was taken before and after a two-week treatment period (Ashley *et al.*, 1996).

Data are available in the file: RELAXATION.CSV

Answer the following research question:

1) Did any of the two relaxation techniques lower heart rate as compared to the control?
    a. Import the data and make sure that the import was successful
    b. What is the random-effects structure based on the experimental design?
    c. What is the fixed-effects structure based on the experimental design?
    d. Fit a linear mixed model using the random effects structure found above.
    e. From the fitted model obtain estimated means and standard errors for each of the three treatments.
    f. Compare the two "active" treatments to the control treatment based on the fitted model.