Teaching and learning statistics: A case study of improving a statistics course

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Abstract

The teaching and learning of statistics in higher education presents several challenges: abstract concepts, lack of pre-knowledge, statistical anxiety and students' motivation. Still, knowledge of statistics is relevant for several reasons: students need to understand research in their field, it is important with statistically literate citizens for society, and there is utility and relevance of statistics for various professions. The present study considers how a statistics course can be designed to support student learning. A focus group study was carried out with five students who had taken a statistics course in order to investigate their understanding and reflections on learning. Students' challenges are discussed in relation to guidelines from the literature of how statistics courses should be designed. Methodological reflections on using focus groups in educational research is offered.

Keywords: Statistics, applied statistics, statistics learning, statistics teaching, method course

Introduction

The teaching of statistics in higher education within an applied context (i.e., with focus on practical problems and where the students' main area is something other than mathematics, such as biology, chemistry, or cognitive science) presents a demanding task, both for teaching and learning (Parker, 2014).

The topic comes with a number of challenges. The area of statistics contains abstract concepts for which the students may not have the necessary mathematical background knowledge to grasp. Students' motivation may also be lacking because of its abstract nature compared with other subjects which the students are studying. The phenomenon of *statistical anxiety* (Zeidner, 1990) is common among students across disciplines and applies

to around 66–80% of students in psychology, education, and sociology (Onwuegbuzie & Wilson, 2010). Statistics anxiety is not only a negative emotion, but it has also been causally linked with reduced performance in many disciplines, such as psychology (Lalonde & Gardner, 1993; Macher et al., 2011).

Regardless of these challenges, the reason why students should learn statistics in an applied context, such as cognitive science, is that the students need this knowledge in order to understand and produce research in their field (Parker, 2014). For fields such as experimental psychology, knowledge of statistics is vital. Further, Immekus (2019) also mentions the importance for society of statistically literate citizens and the utility and relevance of statistics for various professions.

Taking all these challenges into consideration, how can a statistics course be designed to support the learning of statistical concepts in an applied context? As a step towards improved course design, the students' current understanding of an existing statistics course is investigated. By examining students' understanding (both what is understood well and what is understood poorly) through a focus group interview, and relating this to existing literature about the design of statistics courses, some guidelines for the design of a statistical course is arrived at.

The concept of learning in this paper is viewed from a constructivist perspective (Piaget, 1957). This view is also used by Parker when he explores the teaching of quantitative methods in the volume *A handbook for teaching and learning in higher education: Enhancing academic practice,* edited by Fry, Ketteridge, and Marshall (2014): "Students learn by constructing knowledge individually. No matter how clearly a book or lesson explains or illustrates a concept, students will only understand the material after they have constructed their own meaning for what they are learning." (Parker, 2014, p. 351). For example, on a statistics course students construct their understanding of data analysis by practically carrying out hands-on analysis tasks, rather than reading about how it is done.

This paper explores the specific case of a statistics course on the cognitive science bachelor programme at the Department of Applied Information Technology at the University of Gothenburg, with the aim of improving the course. The statistics module is 5 hec as part of a 15 hec campus-based methods course for second year students. Around 30 students take the course. It is an introductory course which deals with statistical techniques such as

correlation, null hypothesis significance testing (NHST), *t* tests, ANOVA, and non-parametric tests, using the statistical software package IBM SPSS. The teaching on the course consists of lectures, group data analysis exercises, and seminars. The course literature is a psychology research methods textbook by Shaughnessy, Zechmeister, and Zechmeister (2014) along with some online material. It is the hope that the findings of this paper could not only be applied to the specific case of the course under study, but also generalised to apply to other statistics courses.

Method

Focus groups as method to study teaching and learning

Focus groups (a group interview with around 4–10 persons) are a pedagogic research method well suited to enhancing teaching and learning and informing curriculum planning and course management (Winlow, Simm, Marvell & Schaaf, 2012). When the students' understanding is investigated, focus group interviews can provide useful data since students verbalise their individually constructed meaning.

Felten (2013) identified several general principles to be followed by inquiries of teaching and learning. Among other things, the inquiry should be based on student learning, it should be grounded in context, and it should be conducted in partnership with students. Similarly, Trigwell (2010) emphasizes that research in teaching and learning should be student-centred. Using a focus group of students harmonises with all these principles.

Focus groups as a method of inquiry also connects to Biesta's (2007) discussion that educational research in general, besides testing the effectiveness of teaching strategies, also has another function: to provide new perspectives on a situation and new ways of looking at reality. Interviews as a method is particularly well suited for this exploratory task.

Method of the present study

A focus group interview of students was used to generate data about students' understanding and reflections on their learning. The students had just completed the course (but before passing it since final grading was not yet complete). The interview lasted around 45 minutes.

Williams and Katz (2001) provides several practical recommendations for making focus groups an effective tool in research on education. Following their recommendations a

number of choices were made for the current study, considering ethics, group size, sampling, questions, and location. First, the ethical part of the inquiry was considered. There are a number of ethical issues that need to be addressed in any research, for instance, as drawn up in the declaration of Helsinki (World Medical Association, 2013). Informed consent was obtained and participants were informed that responses would be anonymous. For this reason, no audio recording was made – instead data was collected using written notes. No identities were written down. It was also explained that the focus group was not a course evaluation meeting, but instead about students' reflections on the course content, that is, statistics. Further, considering group size and sampling for the focus group, a natural group was used, as students who had just taken the course joined. The group size was five students, which is well suited to have an intimate atmosphere but still provoking stimulating discussions. Students with a range of abilities concerning statistics (as estimated by the course leader based on earlier encounters with the students) were recruited to the focus group using convenience sampling. Regarding interview questions, positive and easy-to-answer questions were used at the beginning, in order to get the conversation going. Interview questions concerned students' background knowledge, challenges, and what they learnt and understood well. The focus group was held in a classroom (rather than in an office, which might make students less relaxed).

When the focus group interview was complete, the notes were tidied up in digital form. In terms of data analysis, the data from the focus group was analysed inductively by searching for recurring themes (information related to a particular topic). The analysis was made with the aim of arriving at a description (as complete as possible) of the data and was not driven by any analytical framework.

Results

The analysis of the data from the focus group resulted in the following four themes: pre-knowledge, learning challenges, course revisions, and interesting things learnt.

Pre-knowledge

Students brought up background knowledge which may be useful in order to follow the course successfully. Experience from carrying out studies on earlier courses was valued. This pre-knowledge provided experience to understand how things were connected and to

help see the motivation for some things learnt in the course. It was a consensus that pre-knowledge of mathematics was sufficient. Students suggested that the possibility be given to deepen knowledge about some basic statistical concepts, such as standard deviation, in order to really understand them.

Learning challenges

Some parts of the data concerned which were the most difficult challenges for students and what content was particularly difficult. A specific group of statistical tests, non-parametric tests, was mentioned as difficult to grasp (these were also given the least time on the course). Further, the analysis of complex experimental designs, specifically how to analyse simple main effects was brought up as something unclear (a graphical overview was suggested here). Other difficult issues concern lack of experience (and especially difficult for a beginner just starting out): how to approach non-normal data, what to look for in an SPSS output (since the program outputs much more information than is needed), and which effect size to use for which statistical test. Finally, it was mentioned that it was hard to get an overview of all the tests of assumptions of statistical tests – which ought to be done and which could be skipped.

Course revisions

Some issues that came up did not concern any specific content explicitly but had the form of suggestions for future course revisions. Some students wanted to have a little hand-calculation of statistical tests, not just automated software. More follow-ups (feedback) to the workshops/exercises was mentioned. Students wanted access to correct answers to the workshop/exercises so that they could check their progress along the way. Finally, it was suggested that there would be exercises to design experiments from scratch using various designs before the project work.

Interesting things learnt

The focus group conversations also touched upon what was the most rewarding and interesting that the students had learnt during the course. The normal distribution was mentioned because of its central role in empirical science. Statistical concepts that sometimes occur in journal papers, such as null hypotheses, Type I and II errors, and alpha level, was also considered interesting to learn about. Generally, what students liked was that they learnt how to process data from a study statistically.

Discussion

First, the results of the focus group will be discussed in connection to guidelines for teaching statistics from the literature. The focus of this discussion is the quality of the students' learning on the course. Second, a few methodological reflections on the use of focus groups in pedagogical contexts are offered.

Students' learning

It appeared that lack of mathematical pre-knowledge was not a problem for the students. The fact that earlier courses in the program had included empirical studies helped the students to understand how various parts of data analysis are connected – in this way, students could connect new knowledge to earlier knowledge structures when constructing their understanding. For basic concepts it was suggested by the students that some deepening information should be provided. This is in line with Parker's (2014) suggestion: "Have additional resources or guidance for students to consult if they are unsure or confused about the material. You don't have to set the pace to the slowest learner, but you do need to plan for the students to learn at different paces." (Parker, 2014, p. 351).

One reason why the current course works relatively well is that it involves applying the knowledge in practical contexts. The importance of carrying out practical analysis is stressed by Parker (2014), who emphasises that simply reading about data analysis or to critically review other people's data analysis is not enough; students need to practice handling and analysing data themselves. Working collaboratively, as is done in the current course, in small groups on practical problems promotes learning: "The use of group work, peer mentoring or applying concepts promotes the *deep learning* that embeds lessons more thoroughly and with better longevity" (emphasis in original) (Parker, 2014, p. 351). However, students may not always see group work and peer mentoring as supplying feedback. Students sometimes consider feedback from the teacher as the only feedback of value. This was expressed by the students when they wanted more feedback on the exercises as well as access to the correct answers to the exercises, even though they have worked on the exercises in groups and should be able to get feedback there.

In general it is advisable to have students actually carry out data analysis rather than reading about it. Parker (2014) found that poor courses in quantitative methods "focused more on knowledge of methods rather than practicing how to use them." (Parker, 2014, p. 347).

The course contains computer workshops in groups where students explore many analysis tasks and see the results. This connects to another guideline in Parker (2014), that technology should be used to help students visualise and explore data. Visualising and exploring data help students construct their understanding.

It was surprising that students wished for more hand-calculation of statistical tests. This idea goes contrary to the thinking that the less math involved in applied statistics courses the better (Marson, 2007). Many introductory textbooks have also moved away from hand-calculation to more computer-assisted analysis over time (for instance, Shaughnessy, Zechmeister, & Zechmeister, 2014). Of course, it has to be kept in mind that this may be the opinion only of a few students and may not reflect the opinion of the majority of students on the course.

Whether material is presented in an *abstract* or *concrete* form has consequences for learning. It was been found that understanding depends heavily on the *content* (what things it is about), rather than the *structure* (such as logical structure) of a problem. For instance, the task of checking whether a rule is followed is much more difficult if it involves (the abstract) vowels and even numbers compared to (the concrete) postage and envelopes (Johnson-Laird, Legrenzi & Legrenzi, 1972). Many studies show that concepts in general are easier to learn when the material is concrete rather than abstract (Johnson-Laird, Legrenzi & Legrenzi, 1972; Ainsworth, Bibby & Wood, 2002; Goldstone & Sakamoto, 2003). Therefore, difficult-to-learn abstract concepts could be made more accessible using concrete content in the examples. One example in the area of statistics is in interaction effects of complex experimental designs. Even a two-way interaction can be challenging to grasp given a complicated experiment, let alone three-way or four-way interactions. Realising that the choice of content is important, presenting examples using simple, everyday content could facilitate learning. For example, in a complex design with the independent variables Gender x Hunger x Time-of-day x Cake-type and the dependent variable Taste-rating, a four-way interaction could be described as "It is only for hungry women in the evenings that the

chocolate cake tastes the best". This makes sense intuitively and could help students construct an understanding of interaction effects that could be generalised.

Methodological discussion

One practical issue surfaced concerning the focus group study: it was difficult to recruit students, even as few as five students (from the total of 30 students in the course). Students are busy with other courses and the motivation to participate in a focus group is low, since it is fairly time-consuming for the students to participate.

During the focus group session, another methodological issue became clear. It is difficult to carry out a focus group study with students without the students seeing it as a course evaluation session. Even though it was stated at the beginning of the session and students were reminded throughout, the talk slowly turned from a focus on learning and content into a list of things students didn't like about the course (with parts not directly relevant to learning, such as practical issues about scheduling, purchasing literature, and so on). The moderator may influence this effect as well – if it is the course responsible or a main teacher of the course, it may be seen as a course evaluation meeting. A recommendation based on this is that the moderator should be someone not involved with the course (however, this may not solve the problem and students still need to be reminded of the purpose of the meeting).

There are other more profound potential problems with using focus groups as a means to investigate students' learning and improve course designs that became clear during the data collection. First, students may not know what they don't understand. If so, they cannot possibly verbalise it in a focus group. This could lead to that important parts of problematic teaching is overlooked. Another issue is that even if students know what they don't understand, they may not have good ideas how the teaching and learning should be designed to solve that problem. Students are not educators. Literally following students' ideas for course design may result in a poorly designed course. Instead, the students' ideas should be evaluated in light of the pedagogical approach and overall design idea of the course as based on research on teaching and learning in higher education.

References

Ainsworth, S., Bibby, P., & Wood, D. (2002). Examining the effects of different multiple representational systems in learning primary mathematics. *The Journal of Learning Sciences*, *11*(1), 25–61.

Biesta, G. (2007). Why "what works" won't work: Evidence-based practice and the democratic deficit in educational research. *Educational theory*, *57*(1), 1–22.

Felten, P. (2013). Principles of good practice in SoTL. *Teaching & Learning Inquiry: The ISSOTL Journal*, *1*(1), 121–125.

Fry, H., Ketteridge, S., & Marshall, S. (2014). *A handbook for teaching and learning in higher education: Enhancing academic practice* (4th Ed.). New York: Routledge.

Goldstone, R., & Sakamoto, Y. (2003). The transfer of abstract principles governing complex adaptive systems. *Cognitive Psychology*, *46*, 414–466.

Greenhouse, J. B., & Seltman, H. J. (2018), On teaching statistical practice: From novice to expert. *The American Statistician*, *72*, 147–154, doi: 10.1080/00031305.2016.1270230

Immekus, J. C. (2019). Flipping statistics courses in graduate education: Integration of cognitive psychology and technology, *Journal of Statistics Education*, *27*(2), 79–89, doi: 10.1080/10691898.2019.1629852

Johnson-Laird, P.N., Legrenzi, P., & Legrenzi, M.S. (1972). Reasoning and a sense of reality. *British Journal of Psychology*, *63*, 395–400.

Lalonde, R. N., & Gardner, R. C. (1993). Statistics as a second language? A model for predicting performance in psychology students. *Can. J. Behav. Sci.* 25, 108–125. doi: 10.1037/h0078792

Macher, D., Paechter, M., Papousek, I., & Ruggeri, K. (2011). Statistics anxiety, trait anxiety, learning behavior, and performance. *Eur. J. Psychol. Educ*. 27, 483–498. doi: 10.1007/s10212-011-0090-5

Marson, S. M. (2007) Three empirical strategies for teaching statistics. *Journal of Teaching in Social Work*, *27*(3–4), 199–213. doi: 10.1300/J067v27n03_13

Onwuegbuzie, A. J., & Wilson, V. A. (2003). Statistics anxiety: Nature, etiology, antecedents, effects, and treatments–a comprehensive review of the literature, *Teaching in Higher Education*, *8*(2), 195–209, doi: 10.1080/1356251032000052447

Parker, J. (2014). Quantitative methods in the social sciences. In H. Fry, S. Ketteridge, & S. Marshall, *A handbook for teaching and learning in higher education: Enhancing academic practice* (4th Ed.) (pp. 345–350). New York: Routledge.

Piaget, J. (1957). *Construction of reality in the child*. London: Routledge & Kegan Paul.

Shaughnessy, J. J., Zechmeister, E. B., & Zechmeister, J. S. (2014). *Research methods in psychology* (10th ed.). New York: McGraw-Hill.

Trigwell, K. (2010). Judging university teaching. *International Journal for academic development*, *6*(1), 65–73.

Williams, A., & Katz, L. (2001). The use of focus group methodology in education: some theoretical and practical considerations. *International Electronic Journal for Leadership in Learning, 5*(3).

Winlow, H., Simm, D., Marvell, A., & Schaaf, R. (2012). Using focus group research to support teaching and learning, *Journal of Geography in Higher Education*, *37*(2), 1–13. doi:10.1080/03098265.2012.696595

World Medical Association (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, *310*(20), 2191–2194. doi: 10.1001/jama.2013.281053

Zeidner, M. (1990). Does test anxiety bias scholastic aptitude test performance by gender and sociocultural group? *Journal of Personality Assessment, 55*(1–2), 145–160. doi: 10.1080/00223891.1990.9674054