SHORT UPDATE

Language and Discourse in the Learning of Statistical Concepts

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Abstract

Students on Business School courses will require a certain level of numerical ability; therefore, Mathematics and Statistics are important elements of the curriculum (Cottee et. al., 2014). Students often struggle with these quantitative parts of their course and this is sometimes seen as part of a general "Mathematics Problem" that impacts many disciplines including biology, economics, nursing and psychology (Mac an Bhaird and Lawson, 2012). Many students find Statistics in particular a difficult subject as it includes concepts which are complex and even counter-intuitive. For these students the way in which statistical ideas are communicated and specifically the use of language and discourse are of great importance.

This paper reports on ongoing research into the role of language and discourse in teaching and learning Statistics. Included are: Findings from a Pilot Enquiry carried out in 2019; the theoretical background to the research and the challenges presented by the pandemic both for teaching and for the research.

Keywords: statistics education, pedagogic discourse, language codes.

1. The "Mathematics Problem" and the “Statistics Problem"

Business School students in the UK often struggle with the quantitative parts of their courses. This is sometimes seen as part of a general "Mathematics Problem", noted for example in the ‘Roberts Review’ (Roberts, 2002) and in a **sigma** report on Mathematics and Statistics support (Mac an Bhaird and Lawson, D, 2012).

Statistics can be a difficult subject for non-specialists (e.g., Mustafa,1996; Kruppa et. al., 2021; MacDougall, 2021). It includes concepts, particularly those related to the process of hypothesis testing which are complex and even counter-intuitive (e.g., Kapadia, 2013; Babai et. al., 2006). Such concepts may not easily build on students’ existing mathematical understanding which may include limited exposure to Statistics, as Kruppa et. al. (2021) explains: students must “connect the introduced statistical terms within their personal existing networks of largely non-statistical knowledge" There has been considerable research into how students learn Mathematics and Statistics and how that learning can best be supported (e.g., MacGillivray and Croft, 2011). Mathematics and Statistics tend to be considered as a combined discipline however there have been some studies into the specific problems related to learning Statistics, e.g., Garfield & Ben-Zvi (2007) which identifies “common faulty heuristics, biases, and misconceptions found in college students and adults” as a persistent problem.

Communication and discourse play a very important in learning Statistics, as students need to move between the everyday language used for a business problem and the precise mathematical formulation required for a statistical test. There has been considerable research into the role of communication and discourse in education generally (e.g., Illeris, 2018) and Statistics education specifically (e.g., Garfield and Ben-Zvi, 2007). Of particular relevance is Jablonka et. al. (2012) which explored the Mathematical education of first year Engineering undergraduates using Bernstein’s theory of pedagogic discourse (Bernstein, 1981) as elaborated in section 3 below.

2. Pilot Enquiry

A Pilot Enquiry in 2019 using a combination of questionnaires and interviews investigated students' pre-existing abilities and attitudes in Statistics. The population under investigation was all first-year undergraduates of a university business school (approximately 900 students). This included a wide range of degree subjects with various entry requirements. A sample of 32 students completed the questionnaire. A sub-sample of 4 who were broadly representative of the cohort were selected for in-depth interview. The questionnaire used mainly Likert scale questions to determine attitudes followed by open-ended questions to give respondents an opportunity to expand on their answers.

Although the small sample size precluded drawing any definite inferences, some interesting phenomena did emerge which suggest topics for further study. Students varied in the degree to which they saw Mathematics and Statistics as relevant, either in their course (Figure 1) or personally (Figure 2).

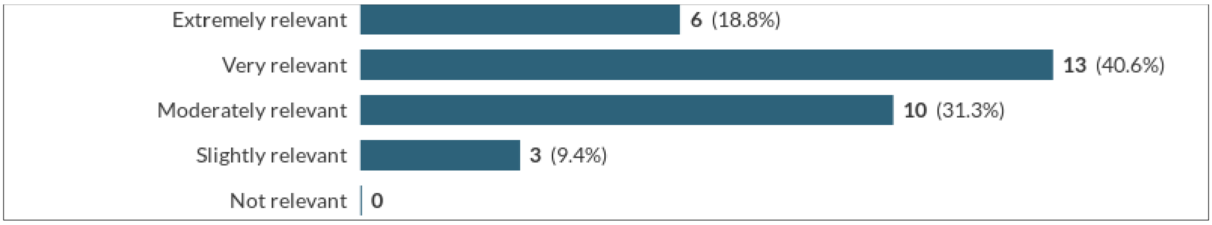

Figure 1. To what extent are Mathematics and Statistics relevant to your course?

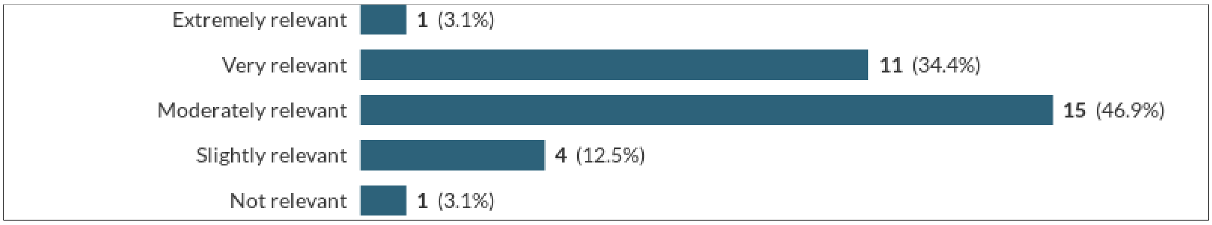

Figure 2. To what extent are Mathematics and Statistics relevant to you personally?

In the open questions and in the in-depth interviews phase it emerged that students differed in their perception of what they considered mathematical or statistical. Some regarded everyday activities as mathematical. Examples cited included: planning the layout of a bathroom; recording and analysing performances in dance competitions; calculating quantities and costs for recipes; and planning a car journey. Others participated in similar activities which included calculating or planning but did not regard these as being strictly mathematical.

Interesting gender differences emerged. On the question "To what extent do you agree with the following statement: Mathematics and Statistics are important only if used for a practical problem?" most male respondents agreed or strongly agreed (56% with 11% neutral) but for females the reverse was true (57% disagreed or strongly disagreed with 19% neutral). However, women students were more likely to cite the previously mentioned everyday uses of Mathematics. It may appear contradictory that most male students see Mathematics as a problem-solving tool but are less likely to perceive everyday problems as being amenable to Mathematics. These findings appear to support the perception of Mathematics as "impersonal, rule-driven, fixed and stereotypically masculine" (Ernest, 1991), perhaps seen (at least by some students) as useful only for well-defined business problems.

Students were asked about their experience of using computer systems in their learning of Mathematics and Statistics. An interesting finding was that students were often unclear about the boundary between a mathematical or statistical technique and the software being used to implement that technique. For example, when learning about correlation and linear regression students may also be learning how to carry out these calculations in Excel. When we discuss the 'tools' used to solve a business problem this could mean a range of things: the method we use (for example a chi-squared test), the symbols and formulae, the software (Excel or SPSS) and the physical computer. In the student's mind the statistical concept would appear to be closely associated with the method or tool used to put into effect the concept.

It was decided to carry out further research into how students construct their knowledge in Statistics, including the way statistical ideas are communicated and where they see the boundaries between Statistics and other disciplines including Business and Computing.

3. Proposed Research

3.1. Overall Aim

The overall aim is to investigate how Business School students learn Statistics. The theoretical framework used will be social constructivism, the idea that students construct statistical and mathematical knowledge from their own experience, individual or social (Cole, 2015). Therefore, the aim can be stated more precisely as "to investigate and model" the *way* in which first year Business School students construct their ideas (individually and socially) and the role of discourse in that construction, using as an example the process of Hypothesis Testing. Hypothesis Testing is used because it incorporates several problematic areas such as conditional probability and inference as well as calculation

In developing a social constructivist model of Business School students' learning of Statistics Bernstein's educational theories will be used as a theoretical lens. This will require precise analysis of the language used in communication statistical ideas. Bernstein sociolinguistic theory of language codes (Bernstein, 1990) will be used to give us a more concrete idea of how statistical knowledge is constructed.

3.2. Theoretical Background

Bernstein's "theory of pedagogic discourse" considers the way discourse (particularly in education) functions in society (Bernstein, 2000). Bernstein viewed "pedagogic discourse" as the means by which notions are structured and reproduced within society. He did not address Statistics specifically, but Bernstein (1990) as cited by Clark (2005) uses the example of Physics which "from its primary location in the universities" is "relocated and refocused it in the secondary school". Bernstein distinguishes between the "message" and the "carrier of the message", i.e., the language and structures. There has been research which has applied Bernstein's theories to undergraduate Mathematics (e.g., Jablonka et. al., 2012; Dowling, 1998), although not specifically to Statistics.

Classification and recognition rules (Bernstein, 1981) are relevant here. Classification refers to 'the degree of boundary maintenance between contents' (Bernstein, 1973) and is concerned with the insulation or boundaries between areas of knowledge and subjects in the curriculum. In the course of their Mathematics education, students move through a range of different mathematical discourses. This can include for example emphasis on informal or formal reasoning; emphasis on practical application or abstract concepts and inductive or deductive reasoning. In the transition from school to university the mathematical knowledge becomes more *strongly classified* (Jablonka et. al., 2012).

Several researchers identify the importance of language and communication in various forms in learning Statistics: Garfield & Ben-Zvi (2007) emphasise the importance of acquiring "Statistical Literacy" as a prerequisite to "Statistical Reasoning and Thinking". Garfield (1995) advocates a 'corrective-feedback' strategy, encouraging students to explain solutions narratively, as a way to help students overcome their misconceptions. Cakir (2009) sees the importance of 'conversations' within small groups of students in the construction of mathematical artefacts. Ernest (2003) sees conversation as a driver in the social construction of knowledge in the classroom but also metaphorically for the historical development of Mathematics.

3.3. Proposed Methodology

An in-depth Case Study will be conducted to investigate conceptual understanding of Statistics over two successive cohorts of the first year of Business School courses and the various ways in which this understanding develops. This will be part action research involving two teaching cycles. The specific methods used for data gathering will be interviews with students, which allow them to "tell their stories", and classroom observation.

4. Pandemic effect on teaching and research

4.1. Research evidence

Online teaching during the pandemic has changed the way ideas are communicated. It has brought into sharp focus the importance of discourse in a quantitative subject. Walker et. al. (2020) notes that it has some advantages but can be seen as a "*potential panacea which can enable scaled delivery*" but "*the amount of work involved in online teaching and marking is being underestimated*". There is conflicting evidence on effectiveness of online teaching. Cassibba et. al. (2021) in study of distance teaching of Mathematics in Italian universities notes: "*The problems of adapting ways of teaching to the new e-learning environment are particularly relevant when teaching mathematics, because of the frequent use of symbols and formulas, as well as gestures and body*."

4.2. Personal experience

Generally online teaching can work well for specific statistical techniques and the software to implement these, but there can be challenges for the more nuanced interpretation and explanation required to solve a business problem using appropriate techniques. The overall picture is more complex: differences in students' backgrounds, prior educational experience and home situation are factors which have a bearing on how successfully they engage as online learners. Often it is the weaker students that need the extra *ad hoc* examples, diagrams, body language, gestures etc.

Online teaching and pandemic restrictions, if these continue will also impact on the research. For example, classroom observation and interviews may need to be conducted on-line. As with the teaching itself it might have the effect of inhibiting some students particularly those who struggle with statistical ideas.

5. Some tentative conclusions

Discourse clearly plays a critical role in teaching and learning Statistics. However, the *nature* of discourse has changed dramatically over the years. Discourse in its widest sense now includes various forms of communication through electronic media, something which lockdown has brought into sharp focus. Bernstein's educational theories are still relevant, but these will need to be adapted for today's technologies.

It is hoped that this research will produce recommendations for teaching materials and methods and take a small step towards answering the “Statistics question”.

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