Statistical literacy in subjects other than mathematics: an exploratory case-study with pre-service science teachers

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This article describes part of a PhD study exploring how statistical literacy knowledge and skills may be transferred from mathematics to other domains, investigating the skills and dispositions of pre-service teachers. I report on an observational case-study of science student teachers on a postgraduate Initial Teacher Education (ITE) course, delivering a model lesson involving statistics to their peers. I discuss my initial investigation with reference to recent international research in the field, finding that the participants have a wide range of statistical knowledge and experience leading to mixed views and dispositions towards the application of statistics in science lessons.

Keywords: statistical literacy; pre-service; teacher education; science

Background to the study

Internationally, most formal statistics education is situated within the domain of the mathematics curriculum at secondary-school level (Burrill, 2011), yet there are opportunities for statistical skills to be utilised (or they are even requisite) in a wide range of other disciplines studied in English secondary schools by learners aged 11 to 18 (Porkess, 2012, 2013). More broadly it has been suggested that the knowledge and dispositions required to be a consumer of statistics - being statistically "literate" – are crucial life-skills for informed, decision-making citizens in modern society (Gal, 2002, 2004; Royal Statistical Society, n.d.). Although there has been some debate over the precise definition of statistical literacy (Rumsey, 2002), Ben-Zvi & Garfield summarise the approach I take in my research:

> The goal of statistical literacy research is to identify the components of literacy, to find ways to equip all citizens with basic literacy skills - such as being able to critically read the newspaper or evaluate media reports. (2004, p. 403)

While statistics can be seen as "an application of mathematics" (Davies, Marriott, & Gadsden, 2012, p. 7) it is questionable how effectively learners can apply or *transfer* their skills to unfamiliar contexts (Leberman, 2006), much less engage with them critically in the manner described above (Gal, 2002, 2004; Halpern, 1998). As a trained mathematics teacher, I am not convinced that the formal study of statistical methods in secondary-school mathematics lessons is necessarily enough to nurture "the idea that it is legitimate to be critical about statistical messages or arguments" (Gal, 2002, p. 19). For these reasons my research will not be restricted to statistical education in the mathematics classroom alone, but to where application or transfer of statistical literacy skills may take place. This current report concludes the findings of one early research activity in my PhD study with pre-service science teachers, considering both the statistical *content* of their teaching as well as how *critically* they engage with statistical methodologies and outputs.

I will begin by explaining how I arrived at this area of research: my statistics subject knowledge as a young teacher was not based in statistical literacy as a consumer of data, or from practical fieldwork applications, but in more formal statistical and mathematical theory. I chose to specialise in statistics as much as was allowed in my mathematics degree yet the content was primarily *abstract* in nature; I did not plan and conduct my own quantitative research activities until well in to my teaching career. Conversely, my colleagues in mathematics teaching may not have chosen to study formal statistics before coming to the profession (in the same way I had avoided other specialist applications of mathematics in order to focus on statistics), I recall some even having serious disdain for the field despite its significant position in mathematics curricula (Assessment and Qualifications Alliance, 2012; Department for Education, 2013) and the role of these dispositions in relation to teaching of the subject could be significant (Dottin, 2009).

My experiences would suggest that alongside a positive disposition towards the subject, student teachers need to be statistically literate themselves in order to nurture statistical literacy in their students, in fact this is a cycle which also extends to practice in initial teacher education (ITE):

> ... teacher educators need not only to build teachers' statistical concepts but also to make teachers aware of how students' conceptual understanding may develop... teachers' thinking is not much different from students and hence the onus is on teacher educators to link, for the teachers, how they are thinking to the ways in which students think. (D Ben-Zvi & Pfannkuch, 2011, p. 331)

Similarly, the "critical thinking" aspects of statistical literacy, as described earlier (Dani Ben-Zvi & Garfield, 2004), can only be nurtured by teachers equipped with the skills and dispositions to do so:

> Critical thinking is indispensible for 21st century teaching and learning. In order for learners to acquire, practice, and perfect their critical thinking, teachers must first possess and develop these very same skills and dispositions. (Yang, 2012, p. 1129)

Unfortunately, while I do agree that these critical thinking skills are "indispensable" for my own student-teachers, during their ITE year there is little time to make up for a lack of prior critical engagement with statistics at undergraduate level or otherwise; (Goldstein, 2006) summarises the situation I now find myself in as a teacher-educator:

> Undoubtedly the most important practical issue concerns the training of teachers in the relevant statistical knowledge and pedagogy… given the meagre resources currently devoted to statistics, for example within PGCE courses, this seems to be a formidable, but not impossible task… Because of the importance of statistics across the curriculum, statistical teacher training needs to be coordinated across subject disciplines… (p. 2)

While I agree with the principles of cross-curricular collaboration (particularly in light of the challenges faced by pupils in transferring statistical skills across the curriculum, as discussed earlier) there is some evidence to suggest that the practical truth is far from this ideal, even "PGCE mathematics course leaders… [have] pointed out that linking statistics to other subjects is not realised in practice in schools..." (Davies et al., 2012, p. 7).

In my later PhD research activities I hope to more fully explore the links between subject-domains and the pre-service skill-set which practitioners in different curriculum areas can bring to the classroom to develop statistical literacy. This report

considers an initial investigation into the subject knowledge and dispositions of pre-service science teachers on the use of statistical skills in their subject.

Methodology

A group of twenty pre-service science teachers were observed peer-teaching their colleagues. In each session three acted as "teachers" with the remaining seventeen acting as "pupils". My observations were to assess all participants' fluency with statistical language and the pedagogical approach taken. These model lessons involved multiple stages of the statistical investigation process (Burgess, 2011): primary (experimental) data collection, graphical display and interpretation of results. These taught sessions were followed by a brief written survey of the participants consisting of open questions eliciting qualitative responses. The participants were asked to respond on the effectiveness of the model lessons for developing statistical skills (specifically, graphical and interpretive), their knowledge and experience of statistics and their views on the teaching of statistics in science. Due to the exploratory nature of this research, rather than undertaking a formal thematic analysis, "critical moments" (Cohen, Manion, & Morrison, 2011, p. 464) from the recorded observations were transcribed and, alongside the written feedback from participants, compiled to offer illustrative points for discussion and to guide my future investigation.

Analysis and Discussion

Upon observation and analysis it quickly became apparent that my assumption that science student teachers would all have significant practical experience in handling data - and therefore a positive disposition towards the development of statistical literacy in their subjects - was incorrect. The level of statistical expertise and experience described by the pre-service science teachers varied dramatically some reported disliking statistics ("my least favourite part of maths") and having little experience in the field, whereas others had studied a significant amount of theoretical, mathematical statistics or conducted large-scale quantitative fieldwork as part of their previous studies.

The student teachers who taught the sessions, as well as the "pupils" (also pre-service science teachers) had all completed more than 120 days of teaching practice as part of their training year. The participants did occasionally describe their experiences in the teaching of statistics in science, one participant summarising that that "kids hate graphs", another described the situation in more detail:

> Pupil 1: I went through like how to draw a line graph with my year 7s, I went through it step-by-step, still didn't get it. Very similar to this but I just think like, we're all adults and that's probably why the kids couldn't get it. (transcribed from recording)

This comment does also suggest that the participant had taught the graphing procedure within their own science lesson rather than utilising pupils' prior knowledge from mathematics. The survey responses offer some further insight into where content was "transferred in" from mathematics or taught within science outright: 17 out of 20 respondents stated that they assumed the statistical content of these model sessions (involving bar charts and line graphs) would be taught in mathematics, but also that science teachers needed to reinforce or reteach such methods, comments included:

> Assumptions made but not always clear in students mind how to draw a graph.
>
> I personally taught some of it in science and did not assume
>
> …graph drawing skills assumed. Expect to teach some stats as it is specific to science at times.
>
> It needs reinforcing by both science and maths teachers. Maths for maths skills - science for interpretation and meaning → graph is not relevant unless it has meaning (responses from post-session survey)

One worrying comment suggested that it was the *quality* of the teaching of statistics within mathematics which was preventing transfer into science lessons:

> I think mostly it's assumed to be done in maths. I've often found though that pupils really struggle with graphs in science so it obviously isn't being taught very well in maths! (response from post-session survey)

Given this strength of opinion it does also make sense to ask the student teachers where these statistical skills *should* be taught, but there was no clear agreement:

> Should be taught in science (and maths) as it doesn't seem to be covered well enough in maths! Science can develop skills by using practical data.
>
> SHOULD be done in Maths! It's a Maths skill?! I need to be able to use it in science.
>
> I feel it is easier to teach in science as it has real world applications and is less abstract than pure maths
>
> Science curriculum is already bursting so not realistic but if possible, I would like to have more time to go through the maths. More communication between departments? (responses from post-session survey)

This variation between students was also evident during the model lessons, particularly views on how to critically engage with the selection of appropriate graphical methods. One of the participants discussed with the teacher leading the model session how they had used a rule-based approach for their choice of graphical display in both their own learning and as a teacher of science:

> Pupil 1: …it was literally "if it's a word, it's a bar chart and if it's a number, it's a line graph" and that's that… I don't know which is right or wrong though…
>
> Teacher 1: No I don't.... it sort of makes... I know it makes sense when you see it
>
> Pupil 1: …I didn't really know the difference and I've just taken that to be that's how you do it. (transcribed from recording)

This is an approach which I have witnessed in the past in both mathematics and science teaching, this reliance on "rules" negating any critical reasoning with their choice of graphical output, a key component of statistical literacy (Gal, 2002). Further still, one student was surprised at how, given the opportunity to discuss the issue, some of the learners really began to question *why* they were handling data in this way: "I didn't realise there was going to be so much, like, discussion about bar charts...." (Teacher 2, transcribed from video recording). Other students *did* take a more critical approach, considering whether or not a particular type of graph was appropriate:

> Teacher 2: It's not a scatter graph
>
> Pupil 2: I think, it's accurately representing the data
>
> Teacher 2: Go on then, what's your correlation there?
>
> Pupil 2: There is no correlation
>
> Teacher 2: Exactly

Pupil 2: What's wrong with that then? (transcribed from recording)

This debate did not reach a particularly satisfying conclusion but does serve to illustrate some serious differences in the dispositions of these student-teachers; the teacher in this case could be considered to be sticking to a rigid rule-structure as described by Pupil 1 earlier, whereas Pupil 2 was taking a more critical approach, considering the purpose of the graphical display in representing their results.

Limitations and follow-on research

This report concludes the findings of my earliest activities in what I hope will build into a more significant project. This case-study has allowed me to see first-hand how statistical content taught in mathematics may (or may not) be transferred to another subject-area, however this research has not significantly explored a number of other elements within statistical *literacy*; the model-lessons did not involve any interpretation of secondary data or written expression of the participants' findings, for example.

Following the peer-teaching activities described here I plan to convene cross-curricular focus groups (student-teachers of Science, Mathematics and Geography) and build a clearer focus for my research. My follow-on research will be exploring the role of statistics in different subjects, particularly that perceived by pre-service teachers in these areas, and crucially how these could involve different pedagogical approaches and nurture different aspects of statistical literacy.

Acknowledgements

This research is part of a PhD study sponsored by The University of Sheffield

References

Assessment and Qualifications Alliance. (2012). *GCSE Specification: Mathematics A*. Retrieved March 18, 2014, from http://filestore.aqa.org.uk/subjects/AQA-4360-W-SP-14.PDF

Ben-Zvi, D., & Garfield, J. B. (2004). Research on Statistical Literacy, Reasoning, and Thinking: Issues, Challanges and Implications. In D. Ben-Zvi & J. B. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning, and thinking* (pp. 397 – 410). Dordrecht & Boston: Kluwer Academic Publishers. Retrieved from http://site.ebrary.com/id/10139730

Ben-Zvi, D., & Pfannkuch, M. (2011). Developing Teachers' Statistical Thinking. In C. Batanero, G. Burril, & C. Reading (Eds.), *Teaching Statistics in School Mathematics - Challenges for Teaching and Teacher Education: A Joint ICMI/IASE Study* (pp. 323–335). Dordrecht: Springer.

Burgess, T. A. (2011). Teacher Knowledge of and for Statistical Investigations. In C. Batanero, G. Burril, & C. Reading (Eds.), *Teaching Statistics in School Mathematics - Challenges for Teaching and Teacher Education: A Joint ICMI/IASE Study* (pp. 259 – 270). Dordrecht: Springer.

Burrill, G. (2011). Part I Global Perspective. In C. Batanero, G. Burril, & C. Reading (Eds.), *Teaching Statistics in School Mathematics - Challenges for Teaching and Teacher Education: A Joint ICMI/IASE Study* (pp. 1 – 4). Dordrecht: Springer.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). London & New York: Routledge.

Davies, N., Marriott, J., & Gadsden, R. (2012). *Teaching Statistics in British Secondary Schools: Statistics Knowledge and Pedagogy in Secondary Mathematics Teacher Training Courses in British Higher Education Institutions*. London: Royal Statistcal Society Centre for Statistical Education. Retrieved from http://www.rss.org.uk/uploadedfiles/userfiles/files/RSSCSE-Teaching%20Statistics%20Trust%20-%20Teaching%20Stats%20in%20British%20Secondary%20Schools%20report.pdf

Department for Education. (2013). The national curriculum in England. Key stages 3 and 4 framework document. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/244221/SECONDARY_national_curriculum3.pdf

Dottin, E. S. (2009). Professional judgment and dispositions in teacher education. *Teaching and Teacher Education*, *25*(1), 83–88. doi:10.1016/j.tate.2008.06.005

Gal, I. (2002). Adults' Statistical Literacy: Meanings, Components, Responsibilities. *International Statistical Review*, *70*(1), 1–25. doi:10.1111/j.1751-5823.2002.tb00336.x

Gal, I. (2004). Statistical Literacy: Meanings, Components, Responsibilities. In D. Ben-Zvi & J. B. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning, and thinking* (pp. 47 – 78). Dordrecht & Boston: Kluwer Academic Publishers.

Goldstein, H. (2006). Studying statistics within the National Curriculum. Royal Statistical Soceity. Retrieved from http://www.rss.org.uk/uploadedfiles/documentlibrary/767.pdf

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. *American Psychologist*, *53*(4), 449–455. doi:10.1037/0003-066X.53.4.449

Leberman, S. (2006). *The transfer of learning: participants' perspectives of adult education and training*. Aldershot, England & Burlington, VT: Gower.

Porkess, R. (2012). *The Future of Statistics in our Schools and Colleges*. London: Royal Statistical Society & The Actuarial Profession. Retrieved from http://www.rss.org.uk/uploadedfiles/userfiles/files/The%20Future%20of%20Statistics%20in%20our%20Schools%20and%20Colleges.pdf

Porkess, R. (2013). A world full of data: Statistics opportunities across A-level subjects. Royal Statistical Society and the Institute and Faculty of Actuaries. Retrieved from http://www.rss.org.uk/uploadedfiles/userfiles/files/A-world-full-of-data.pdf

Royal Statistical Society. (n.d.). *Getstats – Campaigning to make Britain better with numbers and statistics*. Retrieved from http://www.getstats.org.uk/about/

Rumsey, D., J. (2002). Statistical Literacy as a Goal for Introductory Statistics Courses. *Journal of Statistics Education (Online)*, *10*(3). Retrieved from http://www.amstat.org/publications/jse/v10n3/rumsey2.html

Yang, Y. C. (2012). Cultivating critical thinkers: Exploring transfer of learning from pre-service teacher training to classroom practice. *Teaching and Teacher Education*, *28*(8), 1116–1130. doi:10.1016/j.tate.2012.06.007