Descriptive Essay

Introducing undergraduate students to scientific reports

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Abstract

The question of how and when to introduce undergraduates to primary research articles is a perennial problem. We describe here a series of exercises undertaken with Level One students as introductory training towards the reading and presentation of scientific papers at Level Three and the writing up of final year research projects. In the first exercise, students consider the structure of a scientific report and read and evaluate a given research paper. Subsequently, students are asked to imagine themselves as scientific investigators interested in a specific problem. In tutor-led group discussion, they design an experiment to investigate the problem and then individually write a report based on provided data.

Keywords: scientific report writing, experimental design

Introduction

Publication of research articles is vital for the dissemination and validation of evidence in science. Although the sharing of information in this way is the lifeblood of, for example, the biosciences community, neither the skills associated with the reading nor the writing of such papers flows automatically from other forms of writing in which undergraduates will have participated.

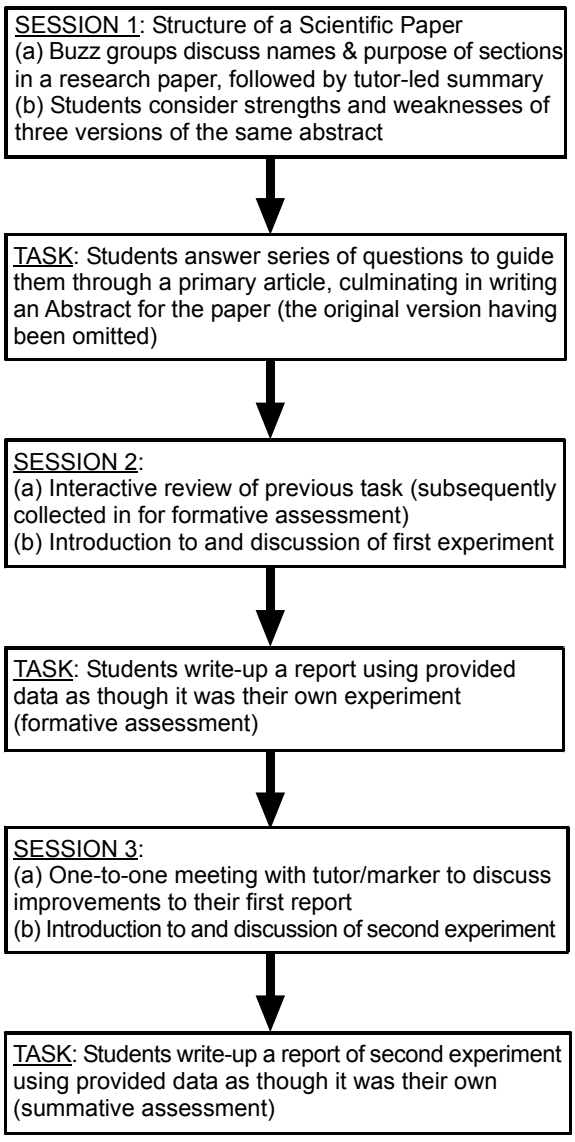
The issue of when and how to expose students to 'real' papers is a dilemma with which many involved in higher education will have wrestled. The expectation that students in the latter stages of an honours degree will be keeping abreast of developments in a particular field of knowledge requires them to become conversant with research articles. Yet the content of such papers is frequently jargon-rich and impenetrable. If the students are to gain more than a superficial understanding of the material presented, indeed if they are going to feel equipped to challenge some of the conclusions made, then they must be helped to see 'below the surface' and examine how the evidence has been put together.

We have, therefore, felt it important to provide students with training in how to handle primary literature. To this end, final-year modules often involve students in 'journal club'-style discussions of papers. We describe here an additional exercise in which Level One Medical Biochemistry and Medical Genetics students (n=70) consider the conventions followed in the preparation of a research paper before engaging in the writing of articles based on provided data. These activities on scientific reports are delivered as part of a wider *Key Skills* module taken by the students throughout their first year of

study. The writing skills component of the module was initially designed and delivered as a collaboration between central teaching and learning services and the academic department, with subsequent development and autonomous delivery by the Biochemistry staff alone.

The report writing component of the module builds on earlier sessions in which students develop several aspects of writing skill *via* such activities as summarising a popular scientific article for a younger readership and correcting grammatical and construction errors in a poor essay (authored by the tutors). The more advanced activities described here (summarised in Box 1) occur in and around three sessions and are introduced to the students as a further development of their abilities to communicate effectively to a scientific audience. Emphasis is placed on understanding of the reported experiment, on logical flow of the writing and on clear and thorough explanation of data. The exercises are put in the context of training for later activities in the degree course such as reading and presenting papers, and the production of reports on final year research projects. Additionally, they impact on more general goals of thinking about experimental design and the ability to read and write scientific papers as the *modus operandi* of communication within the scientific community.

Box 1: Summary of activities involved in report exercise



Session 1: After an introduction along the lines outlined above, the first session begins with buzz groups in which the students are asked to consider the sections they are likely to find in a scientific report and the purpose and content of each section. After ten minutes of discussion, their thoughts are pooled and supplemented by a tutor. In our experience, it is unlikely that participants will suggest the sections of a paper in the 'correct' order (they frequently, for example, neglect to include a title). To reinforce the structure of a paper we have, however, found it helpful to pool their suggestions to the board or overhead projector in a systematic order. This initial feedback progresses into a more formal presentation of the content of each section, during which examples are chiefly drawn from the paper that will become the

focus of the students' personal study task prior to the next session (see below). Reference is also made to the parallels between the process of "doing science" and the structure of any resulting papers as helpfully illustrated by Malmfors *et al* (2000).

Before the session closes with a detailed explanation of the homework, the students are asked to consider in more depth the pivotal role of the Abstract in any report. The use of Title and Abstract in electronic search facilities is emphasised, along with the consequent need to both ensure the inclusion of relevant key words and to write in a way that will encourage prospective readers to seek out the full article. To reinforce this message, students are asked to compare three "Abstracts" for the same fictional paper and asked to comment on the strengths and weaknesses of each. This activity is derived from research carried out by Kirkman in which he used six versions of the text and drew opinion on their relative merits from members of the Biochemical Society (Kirkman, 1992).

Task: The task for students to work on between sessions involves them answering a series of questions to guide them through a primary research article, culminating in the writing of an Abstract for the paper (the original Abstract and citation details having been removed in advance). Given the rudimentary knowledge of the students at this stage in their careers, we spent some while seeking out an appropriate article for this exercise. We were looking for a relatively straightforward report, which would ideally have relevance to other modules being taken by the students at a similar time. Many recent articles are characterised by high levels of assumed knowledge and jargon, and we, therefore, elected to work with a relatively old paper describing experiments on bacterial chemotaxis (Macnab and Koshland, 1972).

Colleagues seeking to set up a similar exercise of their own utilising different material may be interested in the methodology we employed in selecting this article. An initial short-list of possible papers was drawn up from recommendations in the 'selected readings' section at the end of chapters in a major Biochemistry textbook (Stryer, 1995). We then read through the candidate articles before selecting Macnab and Koshland. There were several reasons underlying this choice. The paper describes a classic experiment written in a clear and concise manner, and as such serves not only as a model for the way a report should be written but also as an elegant example of how to design an experiment to investigate a well-defined problem. Furthermore, the content of the article is also useful background material for the *Membranes and Receptors* module running concurrently.

In introducing the activity to the students, we acknowledge that in this day and age they could find their way *via* search engines to the full paper, including the original Abstract, but point out that looking it up would constitute a library skills exercise rather than interpretation and writing, and is not in the spirit of the current task. It is, therefore, gratifying that we have never, to date, been presented with the 'real' Abstract by any participants.

Session 2: In the second session, we make the transition from reading reports to writing them. We, therefore, begin by reviewing the students' answers to the questions posed in the homework. Particular emphasis is given in the discussion to the concept of control experiments since we have anecdotal evidence that many students, encouraged at secondary school to ensure that they have carried out a 'fair test', mistakenly believe that this is the same as carrying out 'controls'. At the end of the review, the Abstracts produced by students are collected in for formative assessment.

Focus is then shifted to planning and reporting an investigation. This exercise could be tied to the write-up of an experiment undertaken by the students. In fact, we have elected, for a number of reasons, to ask them to work with data that we provide as though they have carried out the experiment. This approach allows us to make good use of the available time and to bring out aspects of experimental design in a way that would not be feasible in the context of a teaching practical. Secondly, all practical work in the first year is common both to students on this course and to a wider cohort. We, therefore, felt it would complicate the assessment of this group relative to their peers if they were perceived to be receiving additional help with write-ups of shared experiments.

This is not to say that the experimental problem considered bears no relationship to the content of their other modules. The subject matter for the first report is, in fact, adapted from data described by Kerridge and Tipton (1972) and involves kinetic analysis of lactate dehydrogenase (LDH) – a topic that the students have addressed in the previous semester. Similarly, the second report (see below) involves restriction analysis of genomic DNA and ties in with a parallel module on *Genes and Medicine*.

To engage the students with the data, we introduce each report by asking them to consider how they might set about resolving a particular scientific problem. Students are initially asked to design an experiment to determine whether two 'similar' enzymes isolated from different tissues are, in fact, identical. At this stage they are free to suggest any experimental strategies which they feel would be appropriate. So, for example, the discussion often begins with suggestions relating to structural analysis of the protein(s). This can lead to reflection on aspects of protein purification. Other suggestions from participants will not be appropriate, but rather than dismiss the 'wrong' suggestions out of hand, we have sought to steer the students to appreciate for themselves that the proposed experiment would not provide an answer to the specified question. It is an important component of this process that students begin to appreciate the time required to undertake some of the recommended procedures. They should also be made aware that there may be simpler experiments that could rapidly answer the initial question and/or supply the evidence necessary to justify the commitment of time and money engendered by their ideal solution. Towards the end of this discussion the tutor introduces (if it has not already arisen) the notion that the availability of a suitable assay would allow for comparison of enzyme kinetics and that this may provide an answer rather more quickly than some of the alternative schemes considered.

Having got agreement on the experimental approach to be taken, the students are then presented with the material that they must develop into a scientific report. It is provided to them in the form of pages from a researcher's lab notebook detailing the experiments that have been done and flagging up one or two possible anomalies or points that they would seek to clarify in subsequent experiments. In this way, the students are given insight into note keeping as well as the methods employed and the data that they are to evaluate. They are instructed to write a report as though they themselves had carried out the work and following the scientific conventions discussed in the previous session. They are allowed two weeks to complete the report, during which time they may contact staff for additional clarification regarding the experimental procedures. Given the students' limited practical experience of the techniques described, they are told not to worry unduly about the formatting of the Materials and Methods section. The emphasis is placed instead on appropriate presentation of Figures and Tables and on explanation to their readers of the 'why' as well as the 'what' of the experiments – an aspect of final year dissertations that has traditionally been weak.

Box 2: examples of student feedback

Students were asked in which of the sessions in the key skills programme they had learnt the most and why. Responses included:

Session 1:

"Information about scientific report writing was useful. Group involvement made session interesting"
"I had never seen a scientific report before"
"Helped to explain how to look at and understand how a scientific paper is written"
"I wasn't aware of the structure of reports"

Session 2:

"I had never done anything like writing a scientific report before"
"Didn't no [sic] how to write a report before"
"Dr X went through each stage on how to approach the problem and explained why one method would only take you so far, and how to think about how to tackle a scientific problem"
"Introduction to report was fun and in depth and made everyone take part instead of feeling left out and bored"

One-to-One session:

"Extremely important and very useful. It just picked up on the small areas in report writing that you, as an individual needed to work on"
"Information that was needed most"
"This was most useful as we got to see where we were going wrong and ways to improve our work. This was personal which was good and not aimed at the whole class"

General comments:

"I enjoyed all Key Skills sessions! Despite the reason for going there is always a great atmosphere!"
"The course was very helpful – much more than I had first thought when I started"

One-to-one feedback: Throughout the *Key Skills* programme we pursue a policy that students should have the opportunity to practice any activity before they are formally assessed on similar work. Tutors, therefore, annotate scripts but do not count this piece of work into the assessment of the module. It is an important facet of this process that tutors meet individually for ten minutes with each students whose work they have evaluated: additional staff are recruited to this role, each tutor being assigned 8 students in total with whom they will remained paired for all subsequent assessments in the module. The opportunity for personally tailored feedback is particularly popular with the students (see Box 2).

Report 2: Building on the lessons learnt from completion of the first report and advice received from tutors, the students are then set the task of writing a report on a second set of data. The data is presented to them in exactly the same way as used for the first report, viz a tutor-led discussion of possible experimental strategies to investigate the problem posed and distribution of pages from a researcher's notebook describing the methods used and the results obtained.

The subject matter for this report has changed over the years. This activity was initially based on an experiment involving the incorporation of radiolabelled thymidine into DNA to probe the duration of the mitotic cell cycle (also adapted from Kerridge and Tipton, 1972). The rationale of the study unfortunately proved to be too complicated for some of the participants. This experience illustrates an important tension in the development of activities of this kind. As stated previously, this exercise is designed to develop the students' knowledge of both experimental design and report writing. It is important, however, that if assessment of the latter is to be conducted in a fair manner then by the end of the briefing session all participants should understand how and why the experiment was undertaken. When it was manifest, however, that some students were still struggling to grasp the approach used in the cell cycle experiment, we resolve the difficulty by moving to a more straightforward experiment looking at Restriction Fragment Length Polymorphisms in visual pigment genes (adapted from an exercise in Wilson and Hunt, 2002). This second report is counted towards the student's assessment for the module.

Evaluation

This activity has evolved over several years of use and we are happy that, in its present form, it serves as a cohesive and appropriate introduction to experimental design and the reading and writing of scientific reports for students in the early stages of their undergraduate studies. Box 2 details examples of feedback given by students. Two issues of concern have been raised by students and are worthy of mention here. The first concern related to the difficulty they faced interpreting the cell cycle data for the second report. As outlined above, we have resolved this predicament by moving to a more straightforward experiment for this task. The second concern relates to the perception, by some students, that the effort they put into the first report was not adequately rewarded, as the assessment of this activity is formative. This may be an issue that readers can relate to on their own courses. Although the matter is not clear-cut, we continue to take the view that the benefit from undertaking the first report is derived from the fact that it forms the basis of the one-to-one discussion with a tutor, a facet of the module that is widely appreciated by the students.

We believe that this activity could easily be adapted for use with different biological specialisms. Colleagues who would like more details in order to transplant our materials into their own contexts are invited to contact the authors.

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References

Kerridge, D. and Tipton, K.F. (1972) *Biochemical reasoning.* Menlo Park, California, USA: WA Benjamin.

Kirkman, J. (1992) *Good style: for scientific and technical writing*. London, UK: E. and F.N. Spon.

Macnab, R.M. and Koshland, D.E. jnr (1972) The gradient-sensing mechanism in bacterial chemotaxis *Proceedings of the National Academy of Science* **69**, 2509-2512.

Malmfors, B., Garnsworthy, P.C. and Grossman, M. (2000) Writing and presenting scientific papers. Nottingham, UK: Nottingham University Press.

Stryer, L. (1995) *Biochemistry, 4th Edition.* New York, USA: W.H. Freeman and company.

Wilson, J. and Hunt, T. (2002) *Molecular Biology of the Cell: A problems approach, 4th Edition*. New York, USA: Garland Science.