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On Research Integrity within Science Training

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Abstract

Here we report a teaching practice exploring integrity issues related to the use of images in scientific and/or academic writing or, more broadly, in communication. The practice is intended to raise students' awareness of the need of complying with research integrity principles/norms. It is targeted at undergraduate students in the molecular biosciences, more specifically, to students enrolled in a First Degree in Biochemistry course. It has been implemented in the context of a course unit in which the students perform laboratory work – within a small project – usually originating data that is reported as graphs or as pictures in their laboratory reports. These visual representations are also normally used in articles published in scientific peer-reviewed journals. We implemented a group assignment based on the analysis of guidelines of different journals regarding the preparation of figures, including acceptable image processing and manipulation, as well as on the application of these guidelines on both written and oral reports. We could observe that the students performed the proposed activity with commitment and interest in the aspects explored. Moreover, the exercise improved their critical thinking ability as demonstrated through in-class discussions. In the present work, we discuss challenges of including illustrations in scientific texts in view of science teaching.

Introduction

Resorting to visual representations (e.g., photographs of results of experimental procedures) as a way of providing evidence regarding some claim, is a widely followed practice in the preparation of scientific articles (for a comprehensive analysis see for instance Cambrosio et al., 2008). The practice ascribes to this kind of element a key role in peer communication. At the same time, inadequate image processing or manipulation underlies a significant number of article retractions happening in the broad field of the life sciences and biomedicine (Bik et al., 2016, 2018). This led to a so-called crisis of trust in scientific images and the introduction of guidelines by journal editors, for addressing integrity issues in image manipulation, as presented in this quote:

> The scientific community is increasingly identifying digital image processing as a site of concern in scientific practice, one that has few explicitly articulated norms and conventions. The widespread use of such image processing across the natural sciences, and particularly its rise in molecular biosciences, is being associated with problems relating to the trustworthiness of the published image. Several journals are trying to intervene and help redress this crisis of trust by developing guidelines for image processing. (Frow, 2012, p. 385).

The course unit

The development of the proposed pedagogical activity targets undergraduate students of the second year of the First Degree in Biochemistry course, at the University of Porto, Portugal. The course unit is designated Laboratory of Biophysics/Biochemistry. It is worth 6 ECTS credits (within a cycle of studies of 180 ECTS) and, presently, circa 80 students enrolled each year are distributed across five sections.

The course unit is intended to be interdisciplinary, integrating theoretical concepts and laboratory data relative to various proteins using different biochemistry techniques for their characterisation. The students should learn how to organise, present and discuss the results obtained along the practical classes. The presentation, discussion and critical evaluation of the experimental work developed should be summarised in the form of a written report.

Main outcomes and competences acquired by the students, working in groups of two to three, along this course unit include:

- performing basic laboratory techniques in biophysics and biochemistry;
- interpreting and analysing the obtained results;
- performing written and oral communication of these results; and
- interpreting and analysing scientific peer-reviewed articles involving the techniques studied.

Teaching Practice

Present thoughts emerge from the perception that undergraduate students undertaking laboratory course units should be confronted with integrity aspects in image use and manipulation, especially if the experimental procedures explored lead to visual representations usually included in research articles in the field. Or, more closely, if the students should use these types of experimental results that they obtain in-class in their final reports, a task that should be done according to accepted disciplinary practices. This perception and concern led us to include these kinds of topics in a practical course unit of an undergraduate program in the molecular biosciences starting in the academic year 2017–2018.

The activities within the course unit comprise two main parts: 1) carrying out a mini-project, in the laboratory, spanning several sessions, that culminates with the presentation of results obtained in the form of a written report; and 2) analysis of a scientific publication, from the point of view of how the work was conducted in the laboratory, with particular focus on the techniques used and on complying with the guidelines concerning presentation of results, namely visual representations, according to the scientific journal in question. It also deals with dissemination of research and authorship matters, e.g., transparency on contributions.

Our framework with regard to research integrity is the European Code of Conduct for Research Integrity (ECoC ; ALLEA, 2023). In this code, there is reference to different contexts of scientific activity – the implemented teaching practice spans 'Research Procedures' and 'Publication, Dissemination and Authorship' (fig. 1).

Figure 1. Contexts of the ECoC which the activity refers to

A brief description of the laboratory work is provided here for better understanding the integration of the assignment within the course. As part of the curricular unit students enrol in a small project involving the production and purification of a recombinant protein and the analysis of the process and of the resulting protein. According to the course unit program, this project comprises four laboratory sessions (four practical classes of four to five hours each). After isolation of the recombinant protein from bacteria (1st session), the protein is purified by ion-exchange chromatography (2nd session). In the next step, the purified protein is analysed by polyacrylamide gel electrophoresis (3rd session) and its identity confirmed by western blot analysis with a specific antibody (4th session). Along these experimental sessions, in particular from the 2nd to the 4th session, the results obtained are expressed as a chromatogram, an image of the stained polyacrylamide gel from electrophoresis and ultimately the image of the western blot (immunoblot). While the chromatogram is prepared manually (in this case), images from gel and blot are digitally acquired using adequate equipment and proper image analysis software. The practical work proceeds towards the ultimate goal of the project, determining the 3D structure of the purified protein by X-ray crystallography, even though this is not performed in-class as it would not be feasible. In this second part, the project involves a protein crystallization step and, beyond this, takes advantage of the fact that the results obtained in this type of study end up in an available database, the Protein Data Bank (PDB). In this sense, in the course unit, students explore a published scientific peer-reviewed article reporting the same kind of experimental work and the corresponding publicly available PDB data, the 3D models of the protein structures. The students are able to explore the 3D models by use of molecular graphics software. For this purpose, students explore the atomic coordinates available at the PDB to generate visualizations of these protein structures, fulfilling the applicable guidelines, for example, the need of clarifying the identification of the protein structure and the molecular graphics software used to generate the image. Regarding the previous laboratory work, students have to elaborate a final written report. In the case of the latter task – the analysis of a scientific publication – there is no final written report, but an oral presentation.

The diagram in figure 2 illustrates the different materials at issue, two of them – electrophoresis gels and immunoblots – usually specifically highlighted in the journal guidelines for authors.

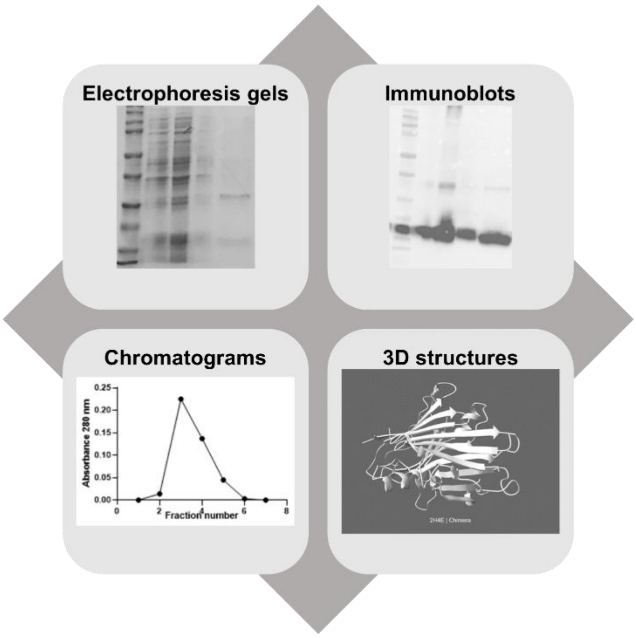

Figure 2. Types of raw images produced within the course unit

In the following section, we describe the assignment proposed to the students to be performed in a practical session lasting for 150 minutes. An important requirement is that the session takes place in a computer room with internet access.

Group assignment

After an introduction in class to the research integrity framework by the teacher who, in this case, is also an expert in research ethics and integrity with experience as member of an Ethics Committee, each group of students is assigned a specific (and leading) scientific journal in the field to explore the guidelines regarding figure preparation and image manipulation. The task to fulfil is to gather information, specially what is closer to the experimental approaches followed in the course unit, to prepare a brief oral presentation summarizing the findings and, finally, to report them to the classmates and participate in a general discussion that is stimulated by the teacher through questions and comments.

In the process, basic rules are expected to be found in the guidelines of different journals, but this result is illustrative of what really matters as good practice in image processing and manipulation. A few examples that can be found in the guidelines of the journals explored are: preserving backgrounds in photographs of electrophoresis gels, using vertically sliced gels only if needed; and preparing composed images of those visuals if it may be justified; but, in any case, always making clear that the resulting illustration is a composition of different parts of a gel (or gels) by maintaining a separation between the slices.

Taking into account the contents of the course unit, so far, the journals chosen for the search have been *FEBS Letters*, *Journal of Biological Chemistry*, *Journal of Cell Science*, *Molecular and Cellular Biology*, *Scientific Reports*, and *The EMBO Journal*.

The level of detail of the different guidelines of the assigned journals is diverse. In some cases, examples of what to do and what not to do are available and this especially catches the students' attention and interest, as their participation in the discussion shows. In the introduction and throughout the final discussion, complementary resources were included. For instance, we referred to news in scientific journals, posts in Retraction Watch, as well as newspaper articles.

Assessment of the teaching practice

Although the implemented pedagogical activity was not formally assessed, in our understanding it added value to the training offered in this particular course unit. Moreover, we could observe that the students performed the proposed activity with interest. The fact that students expressed their surprise regarding some aspects – for example, the rule of preserving the background in images of electrophoresis gels is usually an unexpected requirement – provides evidence for the student about the importance of the assignment.

We can point out different moments throughout the course unit where students have to illustrate their knowledge on these subjects: beyond the class dedicated to the group assignment centred on the journal guidelines, the previously mentioned final oral presentation of a task on the analysis of a scientific publication and, finally, the exam. Since the academic year 2019–2020, these kinds of topics were formally included in the exams.

Even if we firmly defend the importance of including research integrity within undergraduate training, we have to acknowledge a limitation of what we are reporting – the lack of a formal assessment of the activity based on student feedback. In future editions of the curricular unit, we are planning to gather student feedback in order to better adjust a deemed key activity in ways that students perceive as more fruitful.

Discussion and Conclusions

In this work, we reflect on the relevance of addressing research integrity within science training. We particularly focus on requirements relating to illustrated scientific writing for publishing in scholarly journals. As visual representations are often used to provide decisive evidence of what is described in words, focusing on those representations is key in academic writing. Our thoughts draw on the experience of including the theme of research integrity focused on visual representations to prepare students for their use in writing in the scope of undergraduate training in the molecular biosciences. The authors can report that the pedagogical activity described here was successful, in terms of improving students' awareness of research integrity.

The focus on scientific writing in science training has been explored by several authors (see Colabroy, 2011; Lang et al., 2022; Marušić & Marušić, 2003). The relevance of images to communicate science has also been explored (see Watson & Lom, 2008). A brief review of the published literature in a bibliographic database such as PubMed, however, shows that the specific demands addressed in this paper, of ensuring the integrity of supporting illustrations included with scientific writing, are not usually emphasized.

We recommend that this topic should be addressed within undergraduate training. Mostly, because images in the scientific publications are used as decisive evidence regarding some claim presented in the textual part of a document, as we already stated in the beginning of this article.

What are the lessons learned and how they may inform different ways of integrating these kinds of themes in the study plan? Surely, the exploration of research integrity issues may be done in course units specially focused on these topics, but an alternative, perhaps more significant approach is to explore specific problems from this point of view whenever this kind of reasoning can be invoked. The teaching practice we presented is framed in the latter approach. In the curricular unit we teach, it would be unreasonable to discard the opportunity of exploring the question of the integrity of supporting images given the fact the students should consider it in preparing their laboratory reports. From our experience, the so-called vertical approach (Jagger & Furlong, 2014) is feasible. We argue it is of foremost importance, providing background to a more structured and deep study in any specific course unit dedicated to research ethics and/or research integrity.

So far, our approach has been focused on visual representations; the idea, in the near future, is to further develop the approach to encompass other kinds of data produced. The scope of scientific and/or academic writing underlies the described assignment. It seems important for future editions of the course unit and student cohorts to further develop integrity in scientific and academic writing.

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