The Opinion Editorial: teaching physiology outside the box

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Poronnik, Philip, and Roger W. Moni. The Opinion Editorial: teaching physiology outside the box. Adv Physiol Educ 30: 73–82, 2006; doi:10.1152/advan.00075.2005.—Improving the public understanding of science is an important challenge for the future professional scientists who are our current undergraduates. In this paper, we present a conceptual model that explores the role of mass media as community gatekeepers of new scientific findings. This model frames the benefits for undergraduate science students to learn about media genres so that they can learn to communicate science more effectively to nonprofessional audiences. Informed by this Media Role model, we then detail a novel writing task for undergraduate physiology students, the Opinion Editorial (Op-Ed), and an accompanying Peer Review. The Op-Ed genre was directly taught to the students by a professional journalist. As an assessment task, students presented a recent, highly technical paper as an Op-Ed. This was assessed by both faculty members and peers using a detailed assessment rubric. Most students were able to replicate the features of Op-Eds and attained high grades on their writing tasks. Survey data from final-year physiology students (n = 230) were collected before and after the implementation of the Op-Ed/Peer Review. These indicated that most students were aware of the importance of scientists to effectively communicate their knowledge to nonprofessional audiences, that the Op-Ed writing task was challenging, and that they believed that their ability to write to nonprofessional audiences was improved after explicit teaching and feedback.

media; journalism; nonprofessional audience; scientific literacy; survey

It is widely acknowledged by governments, universities, and employers that nonprofessional audiences should be more scientifically literate (4). However, surveys over the past decade have shown that the level of public knowledge remains unchanged despite efforts to popularize science (25). The limited success in broadening public understanding of science may, in part, reflect the diverse definitions of “scientific literacy” used by scholars (12, 23). In the main, academic scientists themselves expend little effort on writing for generalist audiences, and, of more concern, do not “perceive writing as a strategy for constructing understanding” (26). We contend that too little emphasis has been placed on explicitly teaching undergraduates within science disciplines the types of writing best suited to communicating technical science to generalist audiences. Importantly, while there is support for this contention (e.g., Ref. 17) and there is acknowledgement of the growing research into media use of language (6), the details of how this objective might be best taught and assessed are not clear.

The School of Biomedical Sciences at the University of Queensland strongly advocates the acquisition of effective communication skills by their graduates. The final-year course BIOM3006 (Human Physiology and Pharmacology in Disease) has learning goals that specifically align with the development of 1) communication skills appropriate for entry into a science-based workplace, 2) the ability to chose and use the most effective strategies in communicating to the community, and 3) appreciation of the value of science to our culture.

However, when faced with marking scientific reports, many of our faculty members have claimed that “the students can’t write.” This frustration is frequently echoed by employers who value effective communication skills of their employees in the workplace. A recent analysis of essays in BIOM3006 from previous years revealed that most students had a grasp on the mechanics of writing, e.g., grammar, punctuation, and sentence construction. Thus we hypothesised that the key challenge lay more with students lacking formal training in writing and, specifically, in genres of writing intended to clearly inform nonprofessional readers of technical concepts. We then designed a novel assessment task: to introduce BIOM3006 students to writing for a media context, where the required level of understanding includes “the scientific terms and constructs necessary to read a daily newspaper or magazine” (15). An Opinion Editorial (Op-Ed) and a subsequent Peer Review were developed as a two-part assessment task in physiology. The Op-Ed was selected because it requires clear and concise writing of complex biomedical research to inform readers without relevant technical education: broadly, “nonprofessional audiences.” The Peer Review (in which each student formally reviews and grades one Op-Ed from the same cohort) was included to enhance opportunities for students to reflect on the effectiveness and quality of their own writing and the writing of their peers.

This paper reports the findings of an action learning project to address three research questions:

1. Can writing an Op-Ed and Peer Review in undergraduate physiology classes increase student awareness of the importance of media in science communication?
2. Can writing these same tasks be used to demonstrate the difficulties of communicating to the public?
3. Can the writing skills of BIOM3006 students be developed through completing an Op-Ed and Peer Review in physiology?

Context and Research Methods

Context

The course and students. BIOM3006 (Human Physiology and Pharmacology in Disease) is a final-year course in the Bachelor of Science program at the University of Queensland. The key goal of the course is to bring together the diverse learning experiences from their

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various undergraduate courses in physiology and pharmacology. They do this by demonstrating how their core knowledge integrates the development and treatment of human disease. There were 230 students enrolled in 2004.

The Media Role model of science communication to nonprofessional audiences. For the purpose of this study, we identified the professional scientific community, science students, the media, and nonprofessional audiences as the key groups most relevant to our role as educators (Fig. 1A). The formal academic curriculum links faculty members (who are professional scientists) to students. The curriculum, characterized by dense and rich scientific content, is delivered through frequent and reciprocal communicative interactions of teaching and learning. Contrasting this, in the community, direct communication between scientists and nonprofessional audiences (e.g., via public forums) is relatively infrequent and usually is not dense in technical content. Nonprofessional audiences learn the most about science via the mass media, e.g., via Op-Ed newspaper articles (2). The media act as community gatekeepers of new scientific content by interpreting, paraphrasing, reporting, and commenting on the outputs of the professional science community.

The Media Role model positions undergraduate students in the role of the professional media (Fig. 1B). While the students learn about and write an Op-Ed, faculty members act as mentor-gatekeepers of science. There are frequent and information-intensive interactions between the professional scientific community, students, and nonprofessional audiences. This conceptual model frames a number of educational benefits that will result from explicit teaching of the Op-Ed. These are that 1) science students will be more effective in communicating technical science directly with nonprofessional audiences and 2) science graduates employed in media vocations will have a better understanding of science. If successful, generalist audiences could be better informed and more discerning about the quality of scientific information they encounter. Importantly, we believe that all science students should have these opportunities within their Bachelor of Science programs. We distinguish these students from the cohort who want to specialize further in the vocations of science communication and journalism. We thus support broad-ranging educational collaborations among scientists, journalists, and science communicators.

Framework for the action learning project. Kolb’s experiential learning cycle (10) was adopted to frame the learning interactions between faculty members and students’ active learning. For BIOM3006 (Fig. 2), this cycle describes how incremental improvements to writing tasks can be made. In this study, faculty members reflected on the features of effective biomedical writing and then designed explicit learning and teaching activities around the Op-Ed and Peer Review. These were implemented in lectures. Students worked individually to 1) write an Op-Ed and then 2) write a Peer Review of another student’s Op-Ed. Students’ understandings and perceptions of the task were obtained from the students in pretask and posttask surveys. The findings from 2004 generated the next (2005) cycle of experience, reflection, and action as part of the ongoing improvement of the course. In the following sections, each element of the study is described.

Fig. 1. A: canonical educational activities link the community of professional scientists with science students. New scientific findings are communicated to the public largely via the media, which act as community gatekeepers. NP, nonprofessional. B: Media Role model. Relevant communication skills of science students can be facilitated via science students adopting the roles of the media.
**The writing tasks.** Students were given an article: Mattick J. RNA regulation: a new genetics. *Nat Genet* 5: 316–323, 2004 (14). This primary text on “junk DNA” was chosen for two reasons. First, the article proposes a challenging and new theory of DNA, thus requiring high-order critical thinking skills to identify key concepts. Second, Prof. Mattick is a member of the university faculty and is known to many students. Students were required to read this article, write a two-page Op-Ed piece targeted at readers of a local broadsheet newspaper, and then randomly assigned to write a Peer Review of another student’s Op-Ed.

**Support for students.** Students were assisted in several ways to complete the writing tasks. First, a 2-h lecture was delivered by an academic colleague researching the role of “junk DNA.” Second, an experienced journalist from the School of Journalism (The University of Queensland) delivered a 2-h lecture on how the professional media communicate science to the public and on the guidelines for writing an Op-Ed piece. Third, the assessment rubrics for each task were explicitly taught to students by the second author. Fourth, articles on junk DNA from recent media releases and popular science journals and a transcript from a recent television special on junk DNA (the Australian Broadcast Commission program “Catalyst”) were made available on the course website. These served as exemplars of writing for the students. Finally, after students completed the Op-Eds, they were required to review the Op-Ed of one other student and then write a half-page report (5% of total course).

**Assessment.** The Op-Ed submissions (10% of total course) were marked by the authors using comprehensive assessment rubrics that explicitly linked criteria to standards and grades (Table 1). Students then used the same rubric to mark one Op-Ed randomly assigned from their cohort and wrote a 150-word review (Peer Review, representing the next cycle of experience/reflection and action by the coordinator. This cycle then iterates as part of the ongoing improvement of the course.

**Table 1. Assessment rubric used to grade Op-Eds written by students**

<table>
<thead>
<tr>
<th>Content</th>
<th>10 – 9%</th>
<th>8 – 7%</th>
<th>6 – 5%</th>
<th>4 – 3%</th>
<th>2 – 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key facts and ideas of the article are very clearly stated</td>
<td>Key facts and ideas of the article are clearly stated</td>
<td>Key facts and ideas of the article are stated</td>
<td>Key facts and ideas of the article are not stated</td>
<td>Key facts and ideas of the article are not stated</td>
<td>Key facts and ideas of the article are not stated</td>
</tr>
<tr>
<td>Sufficient background is provided to enable very clear understanding of key ideas</td>
<td>Background is provided to enable clear understanding of key ideas</td>
<td>Background is insufficient to enable understanding of key ideas</td>
<td>Background is insufficient to enable understanding of key ideas</td>
<td>Background is insufficient to enable understanding of key ideas</td>
<td></td>
</tr>
<tr>
<td>The presentation flows in a very cohesive and logical manner</td>
<td>The presentation is cohesive and logical throughout</td>
<td>The presentation is mostly cohesive and logical</td>
<td>The presentation lacks cohesion and/or logic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genre requirements</th>
<th>10 – 9%</th>
<th>8 – 7%</th>
<th>6 – 5%</th>
<th>4 – 3%</th>
<th>2 – 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conforms very well to the structure and length of an Op-Ed</td>
<td>Conforms well to the structure and length of an Op-Ed</td>
<td>Conforms adequately to the structure and length of an Op-Ed</td>
<td>Conforms poorly to the structure and length of an Op-Ed</td>
<td>Conforms very poorly to the structure and length of an Op-Ed</td>
<td></td>
</tr>
<tr>
<td>Very clearly addresses the needs of the intended audience</td>
<td>Clearly addresses the needs of the intended audience</td>
<td>Generally addresses the needs of the intended audience</td>
<td>Poorly addresses the needs of the intended audience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is consistent throughout</td>
<td>Is consistent throughout</td>
<td>Is not consistent throughout</td>
<td>Is not consistent throughout</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality of writing</th>
<th>10 – 9%</th>
<th>8 – 7%</th>
<th>6 – 5%</th>
<th>4 – 3%</th>
<th>2 – 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grammar, syntax, and spelling are of a publishable (professional) standard throughout</td>
<td>Grammar, syntax, and spelling are of a high standard</td>
<td>Grammar, syntax, and spelling are of a satisfactory standard</td>
<td>Grammar, syntax, and spelling are of a poor standard</td>
<td>Grammar, syntax, and spelling are of an unacceptable standard</td>
<td></td>
</tr>
</tbody>
</table>
5% of total course), which was graded by faculty members using another rubric (Table 2). After all students received their final mark and feedback, top-ranked students were also given feedback by Prof. Mattick and two university journalists. The Op-Eds of two students were published in the university’s corporate newsletter, UQ News.

Research Methods

Data collection methods comprised the development, administration, and analysis of two surveys (one prewriting task survey and one postwriting task survey); analysis of the final assessment marks; and text analysis of Op-Ed submissions. Immediately before completing both surveys, students were informed about the purposes of the study and advised that their participation was voluntary and anonymous, that they could withdraw from the study at any time, and that their decision would not affect grades for the course. In addition, the survey instruments included written consent.

Prewriting task survey: your initial ideas about science communication. The survey consisted of eight items presented in the RESULTS. Respondents were asked to circle one number on a Likert rating scale (13) from 1 to 5, where 1 is very strongly disagree, 2 is strongly disagree, 3 is neither agree nor disagree, 4 is strongly agree, and 5 is very strongly agree. The results of the survey were subsequently discussed by an experienced professional journalist in a lecture where students were explicitly taught how to write an Op-Ed.

Postwriting task survey: Op-Ed and your ideas about science communication. After completing the Op-Ed, students were again surveyed to determine whether they considered the task to be useful and whether they perceived it had developed their skills and ideas about science communication. This survey consisted of six items presented in the RESULTS. Items were designed to measure 1) to what extent did writing the Op-Ed give the students a deeper appreciation of the role of media and the difficulty in communicating science to the public, 2) if writing the Op-Ed was challenging and valuable to the student, and 3) if the students perceived any changes in their own communication skills. The survey form also allowed for additional comments by students.

Analysis of survey results. Survey analysis was framed around recent guidelines of the American Physiology Society (3). Descriptive statistics of each item of the survey data were calculated using SPSS version 10.0 (Macintosh). These included median, mode, arithmetic mean, and SD. It should be noted that means and SDs are included here as location parameters to report patterns (5). Because survey data are ordinal and often had skewed distributions, the nonparametric Mann-Whitney U-test was used to report two-tailed P values (7). Occasionally, to compare the statistical significance of opinions at the extremes of the Likert scale (i.e., combined 1 and 2 as disagreeing versus combined 4 and 5 as agreeing), Fisher’s exact test was used to report two-tailed P values. This modified χ²-test of significance was appropriate for the small number of data sometimes observed in survey response categories. The internal consistency of all survey items was measured using Cronbach’s α-coefficient using SPSS version 10.0 (Macintosh). An α-value of 0.8 or higher indicates that the survey items reliably measure related themes or constructs.

Analysis of the readability of Op-Eds written by students. Readability refers to the ease of understanding that is dependent on how written texts are constructed (8). Algorithms such as the Flesch reading ease scale have been used since the 1920s as reliable and valid methods to measure the readability of diverse printed media. For example, Roberts et al. (19) demonstrated improved readability of articles submitted for publication to a medical journal after peer review and editing.

In this study, the Flesch reading ease scale, the related Flesch-Kincaid scale (representing readability as a U. S. grade-school level), and the complexity of paragraphs, sentences, and words were measured to compare Op-Eds written by students and professional journalists. The fine-grained analysis of texts thus afforded complemented the more global nature of criteria in the assessment rubric viz. the content, genre requirements, and quality of writing (Table 1).

Many Op-Eds written by students were available as Microsoft Word documents (76%, n = 177). These were analyzed to measure Flesch reading ease, the Flesch-Kincaid U. S. grade level (F-KGL), percentage of text written in the passive voice, and the numbers of paragraphs, sentences per paragraph, words per sentence, and characters per word.

Descriptive statistics (means and SDs) and linear regression analyses were used to compare Op-Eds written by students and BIOM3006 students with Op-Eds written by professional journalists. For the latter, 10 articles on current issues in biomedical sciences were selected from two broadsheet newspapers: The Australian and The Courier Mail.

RESULTS

Prewriting Task Survey: Your Initial Ideas About Science Communication

One hundred ninety presurveys were obtained from 230 students. The average response rate was 83% based on from 188 to 195 responses across the 8 items. The Cronbach’s α-coefficient for this survey was 0.9828, indicating very high reliability of survey items in measuring related themes. Student responses from this survey are recorded against each item of the survey listed below.

Item 1. Nonprofessional audiences get most of their information about current science: A. from reading books; B. from open public forums (e.g., public talks); or C. through mass media. There was strong agreement that nonprofessional audiences received most of their information about current science from the mass media (95% rated 4 or 5, median = 5; Fig. 3A). Conversely, reading books and public forums (e.g., public

Table 2. Assessment rubric used to grade student Peer Reviews of Op-Eds

<table>
<thead>
<tr>
<th>Content</th>
<th>5%</th>
<th>3%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The review addresses all of the criteria for a quality Op-Ed</td>
<td>• The review addresses all of the criteria for an Op-Ed</td>
<td>• The review addresses few of the criteria for a quality Op-Ed</td>
<td></td>
</tr>
<tr>
<td>• Is comprehensive</td>
<td>• Lacks detail</td>
<td>• Lacks detail</td>
<td></td>
</tr>
<tr>
<td>• The review provides a critique of both “strong” and “weak” features</td>
<td>• Critique does not justify why what are “strong” and “weak” features</td>
<td>• The review provides a critique that is only highly negative</td>
<td></td>
</tr>
<tr>
<td>Quality of writing</td>
<td>• Grammar, syntax, and spelling are of a very high standard</td>
<td>• Grammar, syntax, and spelling are of satisfactory standard</td>
<td></td>
</tr>
<tr>
<td>• Length requirement is adhered to</td>
<td>• Length requirement is adhered to</td>
<td>• Length requirement is not adhered to</td>
<td></td>
</tr>
</tbody>
</table>

BIOM3006 assessment rubric: peer review of an Op-Ed (5%). Descriptors are of the top standard for each criterions. Nonsubmissions are marked as 0%.

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Fig. 3. A: student responses to item 1 of the prewriting task survey [Item 1. NP audiences get most of their information about current science: A. from reading books; B. from open public forums (e.g., public talks); or C. through mass media]. B: student responses to item 2 of the prewriting task survey (Item 2. The most effective way to present correct scientific information to the public is: A. through reading books, B. from public forums, or C. through mass media). C: student responses to item 3 of the prewriting task survey [Item 3. The general level of “science literacy” (understanding science) in the community is very low]. D: student responses to items 4 and 5 of the prewriting task survey (Item 4. As an early career scientist, it is very important that you are able to communicate what you know to your NP peers; Item 5. Employers expect that graduates will have above average levels of communication skills). E: student responses to items 7 and 8 of the prewriting task survey (Item 7. You rate your oral communication skills as being very high; Item 8. You rate your written communication skills as being very high).
talks) were both considered to be little used by the public (62% rated 1 or 2, median = 2).

**Item 2.** The most effective way to present correct scientific information to the public is: A. through reading books, B. from public forums, or C. through mass media. Students agreed that the mass media were the most effective way to present correct scientific information to the public (81% rated 4 or 5, median = 4), with public forums (46% rated 4 or 5, median = 4) being more important than books (32% rated 4 or 5, median = 3; Fig. 1B). The biggest perceived difference between what source of scientific information was used (item 1) and what is most effective (item 2) was public forums (medians 2 and 3, respectively, $P < 0.0001$).

**Item 3.** The general level of "science literacy" (understanding science) in the community is very low. Most students agreed that the level of science literacy (understanding) was very low (56% rated 4 or 5, median = 4; Fig. 3C); 12% disagreed with the statement (rating 1 or 2), whereas 32% neither agreed nor disagreed (rating 3).

**Item 4.** As an early career scientist, it is very important that you are able to communicate what you know to your nonprofessional peers. Students strongly agreed that it was very important to be able to communicate their knowledge of science to their nonprofessional peers (88% rated 4 or 5, median = 4; Fig. 3D).

**Item 5.** Employers expect that graduates will have above-average levels of communication skills. Approximately the same percentage of students perceived that employers expected above-average communication skills from science graduates (84% rated 4 or 5, median = 4; Fig. 3D).

**Item 6.** You rate your own ability to communicate scientific facts to nonprofessional peers as being very high. A substantial number of students were confident in their ability to communicate scientific facts to their peers (43% rated 4 or 5); 13% of students were not confident, whereas a large number neither agreed nor disagreed with the statement (45% rated 3, median = 3).

**Items 7 and 8.** You rate your oral/written communication skills as being very high. Approximately 42% of students rated their oral or written skills as being high (rated 4 or 5, both median values = 3; Fig. 3E). There were no significant differences among median values for overall communication (item 6 above), oral, or written skills.

**Op-Ed Assessment**

Op-Ed marks from faculty members. The grades (from a maximum of 10) ranged from 3 ($n = 4$) to 10 ($n = 15$) with a mean score (SD) of 7.4 (1.6) ($n = 232$). A mean score of 74% was high compared with other assessment tasks (e.g., the end of semester exam mean = 63%). One of the top-ranked Op-Eds (by David Wood) is presented in full (Table 3).

Op-Ed marks from peers. These grades (from a maximum of 10) ranged from 3 ($n = 2$) to 9.5 ($n = 8$) with a mean score (SD) of 7.6 (1.4) ($n = 232$). This distribution of scores was not statistically different from grades awarded by faculty members.

**Analysis of Op-Eds Written by Students**

The surface features of Op-Eds written by student and professional journalists were very similar across five measurements (Table 4). There were only two differences. First, Op-Eds written by students were longer than those by professionals (median values of 753 and 408 words, respectively). This reflected the target word count in the assessment. Second, most students used the passive voice, whereas professional journalists did not. In writing the Op-Ed, students had not been given any instructions regarding the use of passive sentences. Linear regressions compared overall student grade with each of the seven “readability statistics.” Three weak correlations were found between the final grade and surface features of student Op-Eds. Students receiving higher marks 1) used fewer passive sentences ($r^2 = 0.4784$), 2) wrote more paragraphs ($r^2 = 0.4925$), and 3) wrote more words ($r^2 = 0.3365$).

**Peer Reviews Marked by Faculty Members**

The grades (from a maximum of 5%) for the Peer Review ranged from 2 ($n = 3$) to 5 ($n = 178$) with a mean score (SD) of 4.8 (0.5) ($n = 230$).

**Postwriting Task Survey: Op-Ed and Your Ideas About Science Communication**

One hundred thirty postwriting task surveys were obtained from 230 students, a response rate of 57%. Cronbach’s $\alpha$-coefficient was 0.9726, indicating very high reliability of survey items in measuring related themes. Additional comments were submitted by 26 students. The majority of these comments (70%) were extremely positive, such as “the best thing I have done at Uni” and “do it again next year.” Student responses from this survey are recorded against each item of the survey listed below.

**Item 1.** After completing this exercise, I have a deeper appreciation of how the media present information to the public. Student responses indicated that writing the Op-Ed gave them a deeper appreciation of the role of the media in communicating science to the public (69% rated 4 or 5, median = 4; Fig. 4A).

**Item 2.** This exercise made me realize the difficulty of being able to communicate scientific concepts to the public in a simple and understandable manner. Most students reported that the Op-Ed made them realize that communicating scientific concepts to the public was difficult (87% rated 4 or 5, median = 4; Fig. 4A).

**Items 3 and 4.** I found this exercise a challenging/valuable learning experience. Clearly, most students found writing the Op-Ed to be both challenging (80% rated 4 or 5, median = 4) and valuable (71% rated 4 or 5, median = 4; Fig. 4B).

**Item 5.** You rate your own ability to communicate scientific facts to the public as being very high. The distribution of student responses on the 1–5 Likert scale was almost identical as for item 6 of the prewriting task survey (45% rated 4 or 5, median = 3). So, after students completed the Op-Ed, there was no significant change in the way the students perceived their ability to communicate scientific facts to the public.

**Item 6.** You rate your written communication skills as being very high. On completion of the assessment task, many students rated their written communication skills as being higher after completing the Op-Ed (54% rated 4 or 5, median = 4; Fig. 4C). However, the differences in pre- and postwriting task survey responses were not quite significant ($P = 0.0507$ by Fisher’s exact test).
In an article that could rock the scientific community, Professor John Mattick states that what was thought to be microscopic trash may in fact hold the key to complexity.

His view follows the finding that so-called “junk RNA” is more likely to be found in complex animals like humans than in simple animals like bacteria. RNA refers to very tiny particles found in cells that act as the go-between for life’s genetic blueprint, DNA, and life’s building blocks, protein.

Protein is the basis of living tissue like human muscle or the leaves of a tree.

While only a few percent of the RNA in humans are known to make protein, the remainder had been regarded as useless garbage, commonly called “junk RNA” by molecular biologists.

Professor Mattick argues that junk RNA is not junk at all. Rather, this type of RNA interacts with both DNA and protein to ensure that the system that makes life is both tough and cost-effective.

His idea, published in the journal Nature Reviews Genetics, also explains why a human is made up of surprisingly few genes and why it took three billion years after the origins of life on earth for multi-cellular animals to arise.

Professor Mattick is so firm in his beliefs that he feels the future of science lies in the research of junk RNA, which may have many other hidden, yet very important, roles.

Already, as an increasing number of these non-protein coding particles are being identified, it is being revealed that many have links to human diseases—thus providing hope for the incurable.

The theory may also hold answers to runaway cell processes like cancer and may help to explain why certain people are more likely to become sick than others.

But in order to understand the theory’s full impact, it is necessary to understand its backdrop.

Before scientists began mapping several animal life-codes, they had a rather narrow opinion about which parts of the genome—life’s instruction manual—were important.

According to the traditional viewpoint, the really crucial things were genes—fragments of DNA that tell RNA to make protein.

This advance from genes-to-RNA-to-protein was virtually a scientific commandment for half a century, leading to a great deal of research being devoted to the small percentage of DNA and RNA that eventually form proteins.

The other 98% of human DNA and RNA that does not make protein was neglected as long commercial breaks that interrupted the main broadcast, a sad fact that Professor Mattick addressed in a Scientific American article as perhaps “one of the biggest mistakes in the history of molecular biology.”

In his view, past efforts to study inherited diseases have stumped researchers because, in their search for a faulty protein, the investigators have ignored the junk RNA at their fingertips.

At the same time, current theories have also struggled to explain why a simple roundworm has a similar number of protein-coding genes to humans, and yet the common rice plant has more than either of these.

According to Professor Mattick, the key to unlocking these mysteries lies in junk RNA, which was first introduced into animals three billion years after the origins of life on earth.

This event took so long in coming because the first life-forms on earth, bacteria, lived comfortably and did not have to compete with other animals.

But once the environment changed, single-celled animals had to become bigger, stronger and possess more complicated internal structures in order to survive. This was made possible by the uptake of junk RNA into the cells of simple creatures.

With time, as animals became more complicated in structure and function, they required more and more junk RNA in order to cope with their increasing complexity.

Complexity, as such, is not created by the addition of more genes, but more interactions formed from fewer units of code - a process John Mattick believes is performed by junk RNA.

Put simply, if genes were words and the sentences these words formed were proteins, then the hard task lies not in writing down a list of randomly generated words, but putting those words into a sentence which is both logical and makes sense.

It now appears that in the cell, junk RNA oversees this whole process by working out a way to create a fluent sentence using the fewest number of words possible.

By choosing which genes to use and the order in which they will occur, junk RNA can manufacture many different types of protein from the same set of genes, explaining the apparent lack of protein-coding genes in humans.

Despite the promise of medical breakthroughs, Professor Mattick believes that it will take time to construct a detailed theory that explains how the DNA, RNA and protein machinery all fit into an interlocking system.

“Within 3 to 5 years, this idea will either be accepted or in the dustbin,” he was reported saying in a recent New Scientist article.

Although Professor Mattick may only be satisfied when his work becomes globally accepted, as a keen scientist myself and a supporter of the proverbial underdog, I’m just happy that bits of RNA long considered trash are finally getting the respect they deserve.

### Course Evaluation by Students

One hundred thirty course evaluations were returned from 230 students, a response rate of 57%. The overall course score was 4.2 (from a maximum of 5), the same as the previous year.

Although few comments were offered about the Op-Ed writing task (as 1 of 6 assessment tasks through the semester), the following student comments were of interest:

- “The task of writing science for the public was very interesting, useful and hard. I don’t think we realise the importance of this tool.”

### Table 4. Comparison of student and professional Op-Eds

<table>
<thead>
<tr>
<th>Op-Ed</th>
<th>FRE</th>
<th>F-KGL</th>
<th>%Passive Voice</th>
<th>Sentences/Paragraphs</th>
<th>Words/Sentences</th>
<th>Characters/Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>40.60</td>
<td>11.78</td>
<td>20.05 (14.82)</td>
<td>1.13 (0.45)</td>
<td>25.11 (4.73)</td>
<td>4.97 (0.23)</td>
</tr>
<tr>
<td>Professional</td>
<td>38.74</td>
<td>11.82</td>
<td>0 (0)</td>
<td>1.35 (0.19)</td>
<td>24.72 (3.18)</td>
<td>4.97 (0.18)</td>
</tr>
</tbody>
</table>

Values are means (SD). FRE, Flesch reading ease scale [from 0 (most difficult text) to 100 points (easiest text)]; F-KGL, Flesch-Kincaid grade level (representing FRE as a U.S. grade-school level). The numbers of sentences per paragraph represent paragraph complexity, the numbers of words per sentence represent sentence complexity, and the numbers of characters per word represent word complexity.
“The Op-Ed was a good idea, though we poor science students need a bit more help with writing journo stuff.”  
Appreciated the chance to “think outside the box.”  
“Who would have thought that in Third Year that we could have an opinion!!?”

**DISCUSSION**

Our study originated from faculty concerns about the need for our undergraduates to become more effective communicators. This imperative derives pragmatically from the increasing competitiveness of funding sources from public revenues as well as from belief that scientific knowledge should inform public policy. Thus there are both ideological and pragmatic dimensions.

Broadly, this study is a practical application of the goals proposed in the charter for global science (2), viz. to share knowledge and engage the community in democratic dialogue. A more specific but long-term goal in our school is to foster in undergraduates their “civil scientific literacy.” This aligns with the recommendation from researchers in science education that the understanding of science should go beyond the learning of concepts and knowing how science operates, to emphasize science as a social process (4). Civil scientific literacy has been described as the cornerstone of informed public policy (23) and interpreted in more practical terms as being able to understand science as written about in a daily newspaper (15).

Our Media Role model was useful in framing the Op-Ed and Peer Review as a novel writing and assessment task for final-year physiology students. This model describes how our undergraduates can better understand the dominant role of the media in communicating science to nonprofessional audiences. Furthermore, it positions communication skills in the context of learning physiology and is, therefore, distinct from vocational “media training” for selected scientific spokespeople and from specialist courses in science communication or journalism. The model helped frame our three research questions.

**Can Writing an Op-Ed and Peer Review in Undergraduate Physiology Classes Increase Student Awareness of the Importance of Media in Science Communication?**

For the first time, the opinions of our final-year physiology students about how they might communicate their technical expertise to nonprofessional audiences were surveyed. In our prewriting task survey, most BIOM3006 students recognized that the mass media play a dominant role in communicating new scientific findings to nonprofessional audiences. After completing the Op-Ed, most students felt they had gained a deeper appreciation for the role of the media in communicating science to the public.

Most students believed that the general level of “scientific literacy” (understanding science) was very low. However, many did not, possibly due to multiple and often conflicting

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**Fig. 4.** A: student responses to items 1 and 2 of the postwriting task survey (Item 1. After completing this exercise, I have a deeper appreciation of how the media present information to the public; Item 2. This exercise made me realize the difficulty of being able to communicate scientific concepts to the public in a simple understandable manner). B: student responses to items 3 and 4 of the postwriting task survey (Item 3. I found this exercise a challenging learning experience; Item 4. I found this exercise a valuable learning experience). C: student rating of their writing skills before and after the Op-Ed writing task.
definitions of scientific literacy (12). Our surveys did not probe how students conceptualized this construct beyond “understanding science.”

Not surprisingly, given that many university students in Australia work to pay for their tuition, students recognized that effective communication skills are valued by employers. Competent expression in literary form is one of the skills most highly prized by employers (11). Indeed, human resource managers tend to employ science graduates not because of their knowledge of the content of a field of study but rather because of the processes that they have learned in mastering the content (20).

Can Writing These Same Tasks Be Used to Demonstrate the Difficulties in Communicating to the Public?

Most students felt that writing the Op-Ed was a challenging but valuable task. Furthermore, most students reported that communicating science to the public can be difficult. There was little shift in their own perception of their communication skills and, specifically, their writing skills. This was not surprising, given that the Op-Ed task was only one element of the course and an even smaller component of the undergraduate degree program. Currently, we are developing a program-wide approach to systematically improve technical writing. When this is implemented, it is expected that students will become more confident in their abilities to communicate science to wider audiences. While most students (~90%) recognized that communication to the public was important and that employers put value on communication skills, only 45% of the students thought that their level of communication skills was high. Furthermore, many students agreed that they were not being skilled adequately in this area throughout their undergraduate degree: an obvious point of concern for faculty members. This study highlighted embedded problems regarding the teaching of scientific literacy. It was recognized by students and faculty members that writing a publishable-quality Op-Ed requires not only knowledge of the genre conventions but also considerable pragmatic competencies. In short, the task was not trivial.

Can the Writing Skills of BIOM3006 Students Be Developed Through Completing an Op-Ed and Peer Review in Physiology?

Despite the concerns summarized above, most students demonstrated that they were able to write an Op-Ed to a high standard. Students were able to write an Op-Ed with features that matched those of professional journalists. This was reflected in close similarity of text features measured in Op-Eds written by students and professionals (Table 4). However, the main difference was that students often used passive voice. This probably reflects the style of formal scientific writing traditionally required in most academic tasks, despite recommendations to use active voice (e.g., Ref. 16) and caveats regarding the use of “distorted passive verbs” (e.g., Ref. 24). While the readability of texts results from complex interactions between the writer and reader (6), the measurement of surface features of text in this study pinpointed some of the ways that students were able to reproduce the Op-Ed genre. The Op-Ed was a discriminating assessment task across the large student cohort. While most students achieved a high grade (mean 74%), there was a wide distribution of grades. That students who received higher grades used fewer passive verbs and wrote more paragraphs and words could reflect their more sophisticated linguistic competencies.

Students enjoyed reading and marking each other’s writing. Peer assessment is a powerful tool to engage students actively in both the course and assessment process (1, 21). When peer reviewing written work, learning occurs at three levels: 1) during writing, 2) while reading the opinions of others, and 3) through the subsequent process of self-assessment/reflection (18), thereby fostering deeper learning. Not only were most BIOM3006 students motivated by the opportunity to review each other’s writing, but they also achieved high marks in both the review and Op-Ed.

Other Outcomes

This study was crossdisciplinary in nature. To be effective, the Op-Ed and Peer Review writing tasks required the collaboration of faculty members from journalism and biomedical sciences who jointly refined and delivered the teaching and assessment tasks. Students responded positively to this team approach. This intervention was very valuable in forcing both faculty members and students to reflect on what scientific literacy means for physiology students. It further strengthened the resolve of faculty members to reevaluate the nexus between what the students know relative to what they need to know and how best to do this.

Future Directions: the Next Iteration

The 2004 iteration of this action learning project has provided faculty with student opinions about effective scientific communication to nonprofessional audiences and evidence of the challenges in teaching this to physiology undergraduates. In 2005, the study is being refined (Fig. 2) to empirically evaluate whether authentic nonprofessional audiences agree that physiology students explicitly taught how to write of an Op-Ed are more effective writers to generalist readers.

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REFERENCES