Teaching students to explain the pathophysiology of diseases to lay audiences with a scaffold that supports student choice

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Abstract

Expert educators in science argue that science graduates are often lacking skills in effectively communicating scientific information to lay audiences. To address this, we designed a project, Communicating Disease, for final-year undergraduate human pathophysiology students. Students chose a disease, a relevant nonscientific target audience, and a mode of communication and produced a communiqué designed to educate the audience on the pathophysiology of the disease. Separately, students justified their choice of disease and target audience. Upon completion of the project, students completed an anonymous questionnaire, and their submitted work was analyzed. Our study demonstrated that students thought it was important to learn how to effectively communicate science to a lay audience and felt that the project had supported them in developing knowledge and skills that enabled them to do so. Students were adequately challenged, and most students gave their best effort to the project, indicating a high level of engagement. Evaluation of student performance was consistent with the students’ own perceptions and showed that most students communicated the pathophysiology effectively to the target audience and appropriately justified their choice of disease and target audience. Nevertheless, opportunities for improvement with some aspects of communication, production quality, and creativity were evident. This model is suitable for a range of scientific disciplines to engage students in developing their ability to communicate scientific information to lay audiences—a skill that it can be argued is vital for improving the scientific literacy of our community at large.

authentic assessment; explaining disease; science communication

INTRODUCTION

Australia’s previous Chief Scientist, Professor Ian Chubb, implored science educators to link classroom topics to the real world and to teach science as it is practiced (15). Similarly, in their Vision and Change report, the American Association for the Advancement of Science (AAAS) urged educators to engage students as active participants and deliver curricula that are outcome oriented, inquiry driven, and relevant (4). In line with these calls, educational researchers have been arguing for a move to increased assessment of students’ ability to perform authentic tasks for decades (14). At its simplest, authentic assessment has been described as assessment in which students are asked to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills (14). Although traditional assessments such as essays and multiple-choice tests may indicate a minimum level of knowledge attainment, many of these assessments are often embedded in the lower levels of Bloom’s taxonomy (1, 11, 12), are not predictive of future performance, and do not provide transferable skills and abilities required in the real world (9). Rather, our focus should be on increasing incorporation of tasks that utilize skills required at the higher levels of Bloom’s taxonomy and, as near as possible, simulate the types of tasks, problems, and outputs required of graduates (21). Implementing more engaging and relevant tasks in our curriculum has been argued to have a positive impact on the quality of learning (3) as well as reducing plagiarism (18).

In science education, authentic assessment tasks are those in which practicing scientists would be typically engaged and could therefore include activities such as reviewing literature and writing a review, conducting scientific inquiry and presenting results in the form of scientific posters and journal articles, and communicating scientific concepts to the public. It is well established that scientific literacy of the public is vital to supporting informed decisions on several issues, ranging from climate change to personal health. Nevertheless, it has been identified that curricula that explicitly teach students to communicate science to the lay audience are significantly underdeveloped (5, 7). As such, Brownell and colleagues (5) and Colthorpe and coauthors (7) argue that undergraduate science programs should embed explicit training in science communication to the general public. Colthorpe and coauthors (7) take this further, stating that effective science communicators should be able to recognize their target audience and then make the science accessible to them.

Research articles have been published on different approaches to promote students’ ability to effectively communicate...
to lay audiences. Moni and colleagues (13) incorporated an assessment task for final-year undergraduate (physiology and pharmacology) students to write an opinion editorial newspaper article explaining recent research to the general public. They found that students recognized the importance of successfully explaining science to lay audiences and the quality of their written work improved with the implementation of specific writing interventions (13). More recently, Petzold and Dunbar (16) focused on the use of approachable language, assessing students on their ability to communicate complex physiological concepts to lay audiences, in both written and verbal communications to volunteer nonscientist visitors to the classroom. They found that students were able to adjust their language to reduce complexity and improve approachability when explaining physiological concepts to the lay audience (16). Kuchel and colleagues (10) introduced an assignment in a when explaining physiological concepts to the lay audience. When assessing students on their ability to communicate complex physiological concepts to lay audiences, in both written and verbal communications to volunteer nonscientist visitors to the classroom. They found that students were able to adjust their language to reduce complexity and improve approachability when explaining physiological concepts to the lay audience (16).

METHODS

Participants and Context

The Communicating Disease project, worth 15% of the final subject grade, was embedded in a final-year human pathology elective subject delivered over a 12-wk semester. Fifty-three students (32 women, 21 men) in nonvocational undergraduate degrees (Health Sciences 60%, Biomedical Science 26%, Human Nutrition 14%) completed the subject and the project. Students were required to decide on a disease from a range of broad categories, which excluded those studied in the subject’s lecture series. Students then selected a nonscientific target audience for their communiciqué, relevant for their chosen disease, and a mode of communication from a provided list: video; website; audio podcast; blog post or newspaper or magazine article; game (video or board game); or story or comic book. In addition, students submitted a referenced academic report that provided an explanation of the relevance of the disease, justification for the chosen audience, and written explanation of the pathophysiology of the disease for a scientific audience. Finally, students presented their work in the classroom by sharing their communiciqué with peers and teaching staff. The written explanation for a scientific audience was not a focus of the present study, which was limited to science communication to a lay audience.

The project was introduced to students in the first week of the semester, both in class (workshop) and via the subject Learning Management System site (LMS; Fig. 1). A comprehensive guide was provided to students (Supplemental Material S1; see https://doi.org/10.26181/f2baf1d9a2e5), which set out the requirements of each component of the project, including a weekly schedule, a template for the academic report, details on limitations to disease choices, marking rubrics, and links to additional resources. Throughout the project, students were continually supported by frequent reminders of expected progress as well as an informative workshop. Additionally, students were required to share their choice of disease early in the semester (via an online discussion forum), to ensure that choices were relevant and appropriate.

Data

To address the aims of the study, student perceptions were determined via analysis of completed student questionnaires. Student performance was determined via evaluation of submitted communiciqués and evaluation of the written reports justifying the choice of disease and target audience. The determination of student performance for this study was conducted independently of assessing student work to determine student grades. The study was conducted with approval of the institution’s Human Research Ethics Committee (HEC18107).
Student questionnaire.
At the end of the semester, students were invited to complete a paper-based questionnaire, which comprised 50 questions that included 4- and 5-point Likert scale questions and open-ended questions (Supplemental Material S2; see https://doi.org/10.26181/5f2bab80c32fa). The questionnaire was administered at the end of class; students were assured that this was a voluntary activity (no incentives were offered), and staff members left the room to ensure anonymity of responses. We included one version of a 5-point Likert scale question (strongly disagree, disagree, neutral, agree, strongly agree) and two types of 4-point Likert scale questions, rating importance (not at all important, not too important, somewhat important, very important) and degree of challenge (not at all challenging, somewhat challenging, challenging, very challenging). The 5-point scale was more appropriate for questions relating to level of agreement, as it provided an opportunity for students to choose a neutral response. The 4-point scale was used when an option to provide a neutral response was not necessary. Forty-eight students completed the survey, which is a response rate of 91%. Descriptive statistical analysis was conducted on the quantitative data. Inductive or data-driven thematic analysis, using the approach described by Braun and Clarke (3a), was conducted independently on the responses to the open-ended questions by two authors. Each author developed a coding structure before they came together to discuss, and ultimately refine, the list of themes identified in the responses. Both authors used the revised coding structure to analyze the comments; themes were iteratively revised by the authors during coding. Frequency of responses within the identified themes is presented quantitatively.

Analysis of reports and communiques.
The authors of this article developed an assessment tool to determine student performance (Supplemental Material S3; see https://doi.org/10.26181/5f2cfb30d52bb). Student performance data and details relating to student choice (disease, target audience, and format of communiqué) were recorded and collated in a spreadsheet. Submitted reports were evaluated for how well the disease and target audience were justified. The quality of the following aspects of the communiqués was determined: 1) pathophysiology explanation; 2) communication (language, flow, how engaging); 3) production quality; and 4) creativity. The assessment tool was designed for all modes of communiqués, including games. There was an expectation that a game would be engaging and include appropriate use and flow of language, albeit in unique settings, such as on a gameboard or on associated game cards. An experienced pathophysiology educator (and author of this article) evaluated the communiqués with the assessment tool, adding comments to explain any extreme or surprising ratings. Ratings by a single evaluator are subjective, so to ameliorate this a sample of three randomly selected submissions were first analyzed by all coauthors of this article together, to discuss and refine the parameters and agree on standards, with the remainder then being completed by one individual. Finally, any communiqués that were rated at the extremes for any criteria were reviewed by a different assessor to confirm those ratings.

RESULTS

Overview of Student Work
Diseases chosen.
Table 1 presents the diseases chosen by students. Immunologic or inflammatory diseases were the most common.

Target audiences.
Across the student cohort, nearly half of the students chose mature adults as their primary audience, with young adults being the next most popular choice (Table 2). Most chose a
non-sex-specific disease, with the remaining leaning heavily toward female-specific rather than male-specific diseases.

**Modes.**
Students chose a variety of formats for their work, with videos and websites the most popular formats (Fig. 2).

**Student Perceptions and Experience**

**Student perceptions of the importance of science communication.**
There was strong agreement (96%) with the statement “It is important for students in science degrees to learn how to become effective communicators of science by communicating scientific results, information, or arguments to a range of audiences, for a range of purposes, and using a variety of modes.” Most students (91%) agreed with the statement “It is important for students in science degrees to learn how to become effective communicators of science to a non-scientific audience,” and 93% agreed that “It is important for students in science degrees to learn how to become effective communicators of science to a scientific audience.”

**Student perceptions of their ability to communicate science to the lay audience.**
There was 88% agreement with the statement “My communication piece will educate my target audience about the pathophysiology of the disease.”

**Table 1. Diseases chosen by students**

| Disease Type                  | Specific Diseases                                                                 |
|------------------------------|-----------------------------------------------------------------------------------|
| Cancers (n = 7)              | Non-Hodgkin lymphoma, pancreatic cancer, acute lymphoblastic leukemia, neuroblastoma, invasive ductal carcinoma (breast cancer), mature cystic teratoma, Hodgkin lymphoma |
| Cardiovascular diseases (n = 1) | Raynaud’s disease                                                                 |
| Genetic diseases (n = 7)     | Marfan syndrome, homochromatosis, Wilson’s disease, Turner syndrome, facioscapulohumeral muscular dystrophy, Duchenne muscular dystrophy, beta-thalassemia |
| Immunologic/inflammatory diseases (n = 15) | Guillain–Barre syndrome, primary sclerosing cholangitis, Graves’ disease, Lambert–Eaton myasthenic syndrome, Hashimoto’s disease, celiac disease, malignant otitis externa (MOE), ankylosing spondylitis, autoimmune gastritis, immune thrombocytopenic purpura, scarlet fever, psoriasis, systemic lupus erythematosus, scleroderma, hemolytic disease of the newborn |
| Infectious diseases (n = 10) | Whooping cough, meningococcal disease, tetanus, Chlamydia trachomatis, hepatitis C, syphilis, conjunctivitis, malaria, poliomyelitis, shingles |
| Metabolic diseases (n = 4)   | Addison’s disease, Pompe disease, hyperthyroidism, mitochondrial disease          |
| Miscellaneous diseases (n = 6) | Endometriosis, gallstones, thrombocytopenia, respiratory distress syndrome of the newborn, polycystic ovarian syndrome, gastroesophageal reflux disease |
| Neurological diseases (n = 3) | Bell’s palsy, narcolepsy, spina bifida                                             |

**Student perceptions of the project: curriculum scaffold.**
Most students rated all components of the scaffold as very important, except for the LMS forums, where <40% of students rated this resource as very important (Fig. 3).

**Student perceptions of the project: knowledge and skill development.**
Most students found that the project helped them to improve their ability to communicate science to a lay audience, learn about a disease in detail, and understand and justify why the target audience needs to learn about the disease (Fig. 4). When asked what new skills were learned from completing the Communicating Disease project, students most commonly reported responses related to the themes presented in Table 3; representative quotes are included. Students most commonly mentioned the skill of being able to communicate science to a lay audience.

**Student perceptions of the project: strengths.**
When asked what the strengths of the project were, students’ most commonly reported responses related to the themes presented in Table 4; representative quotes are included. Students most commonly identified that the project was different from other more standard assignments and promoted development of a range of skills.

**Student engagement.**
There was 94% agreement with the statement “Overall, I have given my best possible effort to this project.”

**Degree of challenge experienced.**
Most students rated completion of various aspects of the project as somewhat challenging/challenging, except for choosing the target audience, where half of the students found it not at all challenging (Fig. 5).

**Student Performance**

**Justification of disease and target audience.**
Generally, students justified their choice of disease and audience well (Fig. 6). Reports that were rated most highly for disease justification provided data from credible sources on disease incidence and prevalence, severity of symptoms, impact on the health care system, and potential impacts on family members and society and, if relevant, details on
preventative measures. Reports that were rated most highly for justification of target audience provided data from credible sources, which showed that the chosen audience was vulnerable to the disease (either as a sufferer or close family member of a sufferer, such as a parent of a young child with a disease) and that potential adverse impacts on the audience due to the disease were significant. Common mistakes included choosing too narrow an audience (e.g., choosing a male-only audience for a non-sex-specific disease) or too rare a disease.

Pathophysiology explanation for lay audience.
Students generally explained the pathophysiology of their chosen disease very well in their communiqué (43% Excellent; 25% Very Good; 17% Good; 15% Fair; 0% Poor). To do well, students needed to include all the key scientific concepts, with the language appropriately translated (perhaps with the use of analogies if appropriate), to make the science accessible and understandable to the target audience. Common mistakes included pitching the explanation too high for the chosen audience and covering scientific information too superficially, thus missing some key information.

Quality of communication.
The quality of the students’ communication to their chosen audience was less well managed compared with the scientific aspects (Fig. 7). To rate highly, students needed to include communication that flowed well with a logical structure, make language choices that were imaginative, memorable, and compelling, and overall include communication that would be highly likely to be interesting and engaging for the target audience.

Production quality.
Generally, students produced communiqués of satisfactory professional quality (18% Excellent; 12% Very Good; 35% Good; 25% Fair; 10% Poor). Communiqués that were rated highly for production quality appeared as professional productions that were error free. They contained very high-quality aesthetics, video and sound (where relevant), and images (where relevant).

Creativity.
Most communiqués were rated as Good or Fair for creativity (19% Excellent; 6% Very Good; 30% Good; 36% Fair; 9% Poor). Ten submissions rated Excellent on this scale, as they were original and highly imaginative and memorable. Submissions rated as highly creative included professional-looking websites with engaging content and multimedia resources, the use of a patient voice to explain a disease, and the use of high-quality and colorful images to engage audiences. One student created a storybook pitched at children and created every aspect (story, characters, and illustrations), including images for children to color in.

DISCUSSION
The main findings of this study showed that students overwhelmingly thought that it was important to learn how to communicate science to lay audiences (96% agreement with this statement) and believed that their communiqué would educate the target audience on the pathophysiology of the disease (88% of students). Most students (94%) agreed
that they had given their best possible effort to the project, which reflected a high level of student engagement, and, overall, student feedback indicated that they felt appropriately challenged. Thematic analysis of answers to open-ended questions identified that the project was perceived as different from other more conventional assignments, as it was engaging and fostered creativity and development of knowledge and a range of skills, including learning how to communicate science to the lay audience. Likert scale data also supported the concept that students thought the project supported development of relevant knowledge and skills. Analysis of students’ work showed that, overall, students were able to effectively communicate science to the chosen target audience and were able to clearly justify their choice of disease and target audience. Communiqués were rated less highly for quality of communication, production quality, and creativity.

**Student Perceptions of the Importance of Communicating Science to the Lay Audience**

Students were overwhelmingly of the opinion (91%) that science students should learn how to communicate science to the nonscientific audience. This finding is in agreement with Poronnik and Moni (17), who found that most of their final-year students (~90%), studying human physiology and pharmacology in disease, recognized that communication to the public was important. These students had written an opinion editorial newspaper article explaining recent research to the general public (17). Similarly, Brownell and colleagues (6) reported that their neuroimmunology students thought that scientists should be able to communicate research results to nonscientists. This cohort was required to transform a primary scientific paper into a one-page summary in the style of an article found in the New York Times (6). Taken together, these results are pleasing, as they indicate strong student support for the inclusion of science communication specific to the lay audience in the undergraduate curriculum. The challenge ahead, therefore, lies in the ability to engage faculty in a systematic approach to embedding science communication curricula across all undergraduate science degree programs.

**Student Perceptions of Their Ability to Communicate Science to the Lay Audience**

In the present study, 88% of students believed that their communiqué would educate the target audience on the disease. This is in agreement with Poronnik and Moni (17), who found that most of their final-year students (~90%), studying human physiology and pharmacology in disease, recognized that communication to the public was important. These students had written an opinion editorial newspaper article explaining recent research to the general public (17). Similarly, Brownell and colleagues (6) reported that their neuroimmunology students thought that scientists should be able to communicate research results to nonscientists. This cohort was required to transform a primary scientific paper into a one-page summary in the style of an article found in the New York Times (6). Taken together, these results are pleasing, as they indicate strong student support for the inclusion of science communication specific to the lay audience in the undergraduate curriculum. The challenge ahead, therefore, lies in the ability to engage faculty in a systematic approach to embedding science communication curricula across all undergraduate science degree programs.

**Table 3. Themes emerging from student responses to the open-ended question, “What new skills do you think you have learned by completing the project?”**

| Theme                                      | Representative Quotes                                                                                                                                 |
|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ability to communicate science to the lay audience (46% of comments) | Explaining a complicated concept in a simple and stimulating platform  
Simplifying science literature and presenting it in a fun and simple way  
Being able to talk about scientific topics with nonscientific audiences  
Video creation/editing skills  
How to make a website animation  
Book and picture editing  
Learning how to explain pathophysiology scientifically  
Communicating effectively with scientific audiences  
Learning how to research a rare disease  
Research and referencing |
| Development of technical skills (21%)       |                                                                                                                                                    |
| Ability to communicate to a scientific audience (9% of comments) |                                                                                                                                                    |
| Research skills (9% of comments)            |                                                                                                                                                    |

n = 38 students; 57 different responses received.
pathophysiology of the chosen disease. Similarly, Brownell and colleagues (6) found in a postcourse survey that all students felt confident in their ability to verbally communicate the scientific information learned in class to lay people and in writing a New York Times-style article. In contrast, Poronnik and Moni (17) found that only 45% of students agreed that their ability to communicate scientific facts to the public was very high. It is possible that student agreement was lower in this study because students were asked to determine if their ability to communicate was "very high," ruling out those students who believed their communication ability was anything less than "very high."

**Student Perceptions and Experience of the Project**

Student feedback indicates that, overall, the Communicating Disease project was challenging for most students. Similarly, Poronnik and Moni (17) found that 80% of students agreed that writing an opinion editorial was challenging. Despite the challenge faced by students in both studies, 71% found the opinion editorial writing task to be valuable (17), and student feedback on the Communicating Disease project was overwhelmingly positive. Likert scale data show that most students in the present study thought that they had learned about the pathophysiology of a disease in a lot of detail, understood why it was important to communicate the pathophysiology to the target audience, felt they were able to justify the choice of target audience with references, and had improved their ability to communicate to a nonscientific audience. When students were asked what new skills they thought they had learned, the most common themes identified were their ability to communicate science to the lay audience (46% of comments) and development of technical skills (21%). Furthermore, most students thought that the components of the curriculum scaffold (workshops, marking rubric, student guide, and online forums) were important for their learning and completion of the project, and these results are echoed by Kuchel and colleagues (10). This highlights the importance of including targeted guidance for students when they are completing authentic tasks requiring them to communicate scientific information to lay audiences.

When students were asked what the strengths of the Communicating Disease project were, the most common theme identified (35% of comments) was that the project was fun, interesting, and engaging, different from other assignments, and one that fosters creativity and a range of skills. This is consistent with a high level of student engagement,
evident with 94% of students agreeing that they had given their best possible effort to the project. In our opinion, this stems from the choice offered to students in the design and production of the communiqué, with freedom of choice over the disease, the target audience, and the mode of communication. This autonomy appeared to give students a high level of ownership of their work and led to high engagement with the task, confirming the advice of Rust (18) that choice of tasks increases intrinsic motivation of students. Similarly, Kuchel and colleagues (10) showed that 65% of first-year biology students thought the highlight of a mini-documentary assignment was due to features that influence motivation, including that it was enjoyable, fostered creativity, and provided freedom of choice. In the mini-documentary assignment, students chose a local environmental issue and had to explain the biology that underpins that issue and communicate the relevance of the biology to a lay audience (17- to 19-yr-olds) in a 4- to 5-min film. In contrast to our curriculum, students did not have choice of the lay target audience and the mode of communication (10).

Analysis of Student Work

Analysis of student work showed that students, overall, were able to effectively communicate the pathophysiology of a disease to the target audience and justify their choice of disease and audience. Similarly, Poronnik and Moni (17) reported that most students demonstrated an ability to write an opinion editorial to a high standard and found there was little evidence for the common claim from teaching staff that students are unable to write at a high standard.

Communiqués were rated less highly for quality of communication, production quality, and creativity. It is not surprising that production quality was less well managed, given that little support was provided beyond directing students to a range of tools and resources. As such, consideration is being given to what further scaffolding or resources could be provided, including explicit teaching on media communication or storytelling, in consultation with colleagues teaching in media studies. Nevertheless, the degree of creativity that some students incorporated into their submissions was pleasing. Many of the websites were of a high professional standard, with an excellent balance between the use of text and images and language pitched well to engage the chosen audience, as urged by Colthorpe and colleagues (7). Several students chose to include a character of a “sample patient” to explain their disease, like the use of pop culture icons reported by Zehr (22), and this personification is likely to be highly engaging. Others used animation tools to explain biological processes or produced videos of an exceptionally high standard. The greatest creativity was observed in the production of a children’s storybook, where the student created an original story line of a child with a disease, explaining the pathophysiology and treatment to her friends, and using analogies from the school garden to explain the functions of...
different cell types. The student produced all text and illustrations for the book, in a format for readers to color in. Indeed, Villarroel and colleagues (19) advise that a rich context and worthwhile tasks contribute to students achieving higher learning outcomes.

Conclusions
In summary, the purpose of this study was to determine student perceptions and experience of, and student performance on, an authentic assessment task that required them to explain the pathophysiology of a chosen disease to a lay audience after independently choosing the disease, target audience, and mode of communication. Our study demonstrates that students thought it was important to learn how to effectively communicate science to a lay audience and felt that the project had supported them in developing knowledge and skills that enabled them to do so. Students were adequately challenged, and most gave their best possible effort to the project, indicating a high level of engagement. Evaluation of student performance is consistent with the students’ own perceptions and shows that most students were able to communicate effectively to the target audience and were able to appropriately justify their choice of disease and target audience. Nevertheless, opportunities for improvement in aspects of communication, production quality, and creativity were evident. A limitation of the assessment of the student communicative skills was that the assessors were academics with scientific backgrounds and not members of the target audiences. As such, the authors would like to explore opportunities to increase the authenticity of the project through engagement with members of the intended audiences. The model described in this article could be adopted across a range of scientific disciplines to engage students in developing their ability to communicate scientific information to lay audiences—a skill that it can be argued is vital for improving the scientific literacy of our community at large.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

L.L. and B.L.J. conceived and designed research; L.L., B.L.G., and B.L.J. performed experiments; L.L., D.W., B.L.G., and B.L.J. analyzed data; L.L., D.W., and B.L.J. interpreted results of experiments; L.L., D.W., and B.L.J. drafted manuscript; L.L., D.W., B.L.G., and B.L.J. edited and revised manuscript; L.L., D.W., B.L.G., and B.L.J. approved final version of manuscript.

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