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Appendix

Integrating Communication Skills into Undergraduate Science Degrees: A Practical and Evidence-Based Approach

Supplementary Material Table of Contents

APPENDIX 1: DESCRIPTION AND DETAILS OF THE SEVEN LEARNING ACTIVITIES DESIGNED AND IMPLEMENTED TO SUPPORT EXPLICIT TEACHING OF SCIENCE COMMUNICATION SKILLS

Activity Name: Jargon translation
Duration (minutes): 30
Communication Skills Taught: Consider a target audience
Use language that is appropriate for your target audience
Separate essential from non-essential factual content in a context that is relevant to the target audience
Course: BIOL3000, PHYS3900, CHEM2052
Teaching Documents: Teaching notes for delivery, Student handout
Format: Written
Description: This activity guided students through an easily-applied, step-by-step process for translating complex scientific language into language that was understandable and accessible for different, non-scientific target audiences. Students work through one example as a class and then practice this by taking complex science definitions and translating them for pre-specified audiences on a worksheet in pairs. This activity allows course coordinators to teach/include scientific content that is relevant to their courses as well as equipping students with a skill that will be applicable in many situations throughout their degree and career.

Activity Name: Effective Data Visualisation Through Infographics
Duration (minutes): 20
Communication Skills Taught: Use language that is appropriate for your target audience
Separate essential from non-essential factual content in a context that is relevant to the target audience
Create/use style elements (diagrams) appropriate for the mode of communication
Course: CHEM2052, PHYS3900
Teaching Documents: Teaching notes for delivery, Student handout
Format: Multimedia, Written
Description: This activity started with a class analysis of two diagrams: one the original table from the scientific literature, and the other an infographic visualisation of that data. Students worked as a class to create a list of what makes an engaging infographic and to decide what to do and what not to do when visualizing data for a non-scientific audience. Students were then presented with a data set and asked to work in groups of four to draw their own infographic which visualised the given data in the most effective way on a sheet of butcher's paper. Prizes were given for the best infographics. This activity gets students to actively engage in the process of data visualisation rather than just being told outright, and teaches students to synthesize data sets and to apply some of the basic skills of effective science communication. This activity also worked well as a class 'icebreaker.'

Activity Name: Communicating with Style: Analogy, Metaphor, and Simile
Duration (minutes): 30
Communication Skills Taught: Consider a target audience
Use language that is appropriate for your target audience
Separate essential from non-essential factual content in a context that is relevant to the target audience

Create/use style elements (analogy, metaphor, and simile) appropriate for the mode of communication
Consider levels of prior scientific knowledge in the target audience

Course: PHYS3900
Teaching Documents: Teaching notes for delivery, Student handout
Format: Oral, Written
Description: This activity started with an introduction to analogy, metaphor, and simile: explaining how they are used, their strengths and weaknesses, and why they are useful for science communication. Students were then given three complex scientific concepts and asked to explain each concept to three different, pre-specified, non-scientific audiences using an analogy, metaphor, or simile that simplified the explanation and made the science accessible to the target audience.

Activity Name: Stakeholder Analysis
Duration (minutes): 30
Communication Skills Taught: Consider the social, political, and cultural context of the scientific information
Course: BIOL3000
Teaching Documents: Take-home student worksheet
Format: Written
Description: This activity was given as a take home worksheet as part of BIOL3000. Students were asked to identify all the potential invested stakeholders in a conservation issue in regards to cultural, political, economic, and social investment and then to identify and analyse the three main stakeholders in regards to how and why they might be invested in the issue. This activity allowed students to consider all aspects of a conservation issue alongside the science involved in the topic.

Activity Name: Science Communication Speed Dating
Duration (minutes): 15
Communication Skills Taught: Consider a target audience
Use language that is appropriate for your target audience
Separate essential from non-essential factual content in a context that is relevant to the target audience
Course: PHYS3900
Teaching Documents: Teaching notes for delivery
Format: Oral
Description: This activity was used as an 'icebreaker' at the start of the course and as an introduction to science communication. Students were asked to pair up and over four rounds were given four science concepts to explain verbally to their respective partners who enacted being a specified non-scientific target audience. Each round lasted two minutes and then the roles reversed in the pairs so that each had a chance to do the explaining. At the end of the speed dating round there was a class discussion about what the most important considerations were in regards to communicating science to non-scientific audiences which meant students were actively engaged in the learning rather than just receiving the information outright. The activity made students communicate science and then allowed them to analyse the results of this interaction, as well as getting them to recall scientific information. It was a good way to warm up the class in the first tutorial and helped students to realise that science communication is perhaps not as easy as some might think. This helped reinforce the importance of learning these communication skills.

Activity Name: Target Audience Analysis: Radio
Duration (minutes): 25
Communication Skills Taught: Identify a suitable target audience
Identify the purpose and intended outcome of the communication (Element Nine)
Consider the social, political, and cultural context of the scientific information
Course: BIOL3000
Teaching Documents: Teaching notes for delivery, Student handout, Radio segment
Format: Multimedia, written
Description: Students were asked to listen to a five-minute radio segment on a controversial conservation issue and then form groups to analyse: the main messages; the potential interested audiences; the main invested stakeholders in the issue with regards to culture, economy, politics, and social groups; the opposing arguments in the segment; and the purpose and outcome of the segment. These were then summarised in groups and presented to the class for discussion.

Activity Name: Target Audience Analysis: Video
Duration (minutes): 20
Communication Skills Taught: Identify and understand a suitable target audience
Consider the social, political, and cultural context of the scientific information
Consider levels of prior scientific knowledge in the target audience
Course: CHEM2052, PHYS3900
Teaching Documents: Teaching notes for delivery, Student handout
Format: Multimedia, written
Description: Students were asked to watch a three-minute science video and then as a class to discuss what some of the main considerations which might have influenced the authors in making the video. They then worked in pairs on a worksheet that guided them through the process of audience analysis for who they considered to be the target audience of the video. This activity gets students to actively engage in the process of audience analysis rather than just being told outright, and introduces them to some of the central considerations of communication as well as the mode of communication on which they are being assessed (video—for CHEM2052).

APPENDIX 2 EXAMPLE OF A SCIENCE COMMUNICATION 'TEMPLATE PACKAGE' ACTIVITY

TEACHING NOTES: JARGON TRANSLATION ACTIVITY

Summary: This activity guides students through an easily-applied, step-by-step process for translating complex scientific language into language that was understandable and accessible for different, non-scientific target audiences. Students work through one example as a class and then practice this process by taking complex science definitions and translating them for pre-specified audiences on a worksheet in pairs. This activity allows you (the teacher) to teach/include scientific content that is relevant to your courses as well as equipping students with a skill that will be applicable in many situations throughout their degree and career.

This activity can be used as a follow on from the audience analysis activity, or in isolation, and can be used to develop communication skills once a target audience has been identified or explained. This can be given as either a take home work sheet, or something you work through together in class. Either way it's a good idea to introduce the concepts involved and work through an example with the students as a class or in groups.

You can follow this structure as an introduction:

In the following activity we are going to learn to use some skills that are central to effective science communication:

- Use language that is appropriate for your target audience
- Consider the levels of prior knowledge in the target audience
- Separate essential from non-essential factual content in a context that is relevant to the target audience

The following quote was taken from an editorial published in the scientific journal, *Nature*:

> *It is often seen as a badge of academic credibility to express short simple ideas in long ponderous phrases; why else would anyone choose to write a sentence such as "To elucidate these issues, we utilized the caprine model" instead of "We studied these questions using goats"?*

Scientists often fall into the trap of believing that the more jargon they use, the more professional they sound. Another common belief is that you can't be scientifically accurate without using jargon. Both of these beliefs aren't always true but unfortunately they have made translating 'science language' into 'general language' into a very difficult task.

So as you begin to communicate science, keep in mind a specific target audience. Adapt the language you use to ensure that your audience can understand everything you say. Here are some examples of questions you should consider:

- What prior knowledge in science will your audience already have?
- How much jargon should you use? Would you use the term: Lacrimation or crying? Herbivore or planting eating? Sessile or not moving?
- Will you use acronyms?
- What scientific content will you need to explain? What scientific content can you assume your audience will understand?

We're going to work through an activity together as a class which will get you started on thinking about the answers to some of these questions.

I've written a scientific definition on the board (see below for worked example).

I want you to think about how you might translate this concept to make it understandable and clear to a 15 year old high school student named Jimmy. Jimmy is your target audience.

Look at the scientific explanation. Is there any context which is NOT essential to the explanation? What words or concepts can we remove without making the meaning incorrect?

➔ *Cross out the content identified by the class as unessential.*

Have a think about how much prior knowledge in science Jimmy is likely to have. Which words do you think he might not understand?

➔ *Underline or circle each word mentioned by the class.*

So now that we have a list of words that we know we shouldn't use, let's start translating them.

➔ *Work through the list of words by asking students to break them down into very simple language.*

Now we can use these simplified words to rephrase the original scientific explanation simply by replacing the jargon with our new simple language, and removing the unessential content.

➔ *Rewrite the original explanation on the board with jargon replaced and unessential content removed.*

Hand out the student worksheets and either ask the students to work through the concepts on the worksheet in pairs or give it as a take-home exercise. They can do this using the process we used in the in-class worked example.

WORKED EXAMPLE: SCIENTIFIC CONCEPT: THE GREENHOUSE EFFECT

SCIENTIFIC EXPLANATION

The greenhouse effect is the phenomenon whereby the earth's temperature rises which is caused by the presence of chemical compounds in the earth's atmosphere called greenhouse gases, such as water vapor, carbon dioxide, and methane, which trap short-wave infrared solar radiation.

SCIENTIFIC EXPLANATION WITH **JARGON** AND *UNESSENTIAL CONTENT* HIGHLIGHTED.

The greenhouse effect is the **phenomenon** *whereby* the earth's *temperature rises* which is caused *by the presence* of **chemical compounds** in the earth's **atmosphere** *called greenhouse gases*, such as **water vapor, carbon dioxide, and methane**, which trap **short-wave infrared solar radiation**.

Jargon translation or simplification suggestions:

Temperature rises = warms
Phenomenon = effect
Chemical compounds = chemicals or gases
Short-wave infrared solar radiation = heat from the sun
Atmosphere = the air surrounding the earth
Called greenhouse gases = unessential content
Water vapor, carbon dioxide, and methane = unessential content

SIMPLE EXPLANATION

The greenhouse effect keeps the earth warm. This effect is caused by chemicals in the air that surrounds the planet which trap heat from the sun.

STUDENT WORKSHEET/HANDOUT: JARGON TRANSLATION ACTIVITY

The following activity will help you to:

- Consider a target audience
- Use language that is appropriate for your target audience
- Consider the levels of prior knowledge in the target audience
- Separate essential from non-essential factual content in a context that is relevant to the target audience

This quote was taken from an editorial published in the scientific journal, Nature:

"It is often seen as a badge of academic credibility to express short simple ideas in long ponderous phrases; why else would anyone choose to write a sentence such as "To elucidate these issues, we utilized the caprine model" instead of "We studied these questions using goats"?"

Scientists often fall into the trap of believing that the more jargon they use, the more professional they sound. Another common belief is that you can't be scientifically accurate without using jargon. Both of these beliefs aren't always true but unfortunately they have made translating 'science language' into 'general language' into a very difficult task. So as you begin to communicate science, keep in mind a specific target audience. Adapt the language you use to ensure that audience can understand everything you say. Here are some examples of questions you should consider:

- How much jargon should you use?
  - Lacrimation or crying? Herbivore or planting eating? Sessile or not moving?
- Will you use acronyms?
  - Carbon dioxide vs CO_2?
- What prior knowledge in science will your audience already have?
- What scientific content will you need to explain? What scientific content can you assume your audience will understand?

The following activity is designed to help you get started on the process of jargon translation. In the first column are scientific concepts that a [NUMBER] year [DISCIPLINE] student can be expected to understand. Your job is to explain each concept to two audiences:

1. The first audience is a scientist of the same discipline.
2. The second audience is a non-scientific audience of [SPECIFY].
   - For example, this could be a 10 year old child, a financial businessman, a journalist. Be imaginative!

Consider the above questions as you explain and translate these concepts. Keep sentences short and your word count to an absolute minimum. The first row is filled out for you to remind you of the process we applied during the in-class worked example.

Tip: After defining the concept for the first scientific audience, go through and underline any words that your non-scientific audience might not understand. **Make a list of these and then translate each word into clear and simple language** which you can then use when you write the second explanation for your non-scientific audience.

Tip: Separate essential content from non-essential content. What prior knowledge does your audience already have? What information does your audience absolutely need to know to understand the concept? What information isn't relevant and could be removed? Go through your scientific explanation and cross out any unessential content before re-writing the explanation for your non-scientific audience.

REMEMBER THESE SIMPLE STEPS:

1. Identify jargon and make a list.
2. Translate those jargon words into simple, everyday language.
3. Remove any words or content which aren't absolutely essential to the concept explanation.
4. Rewrite the original, scientific explanation by replacing jargon with your translations, and removing unessential content.
5. Voila! You're on your way to being an excellent science communicator!

Scientific concept	**Explanation for a scientist of the same discipline**	**Explanation for your [insert specific non-scientific audience]**
EXAMPLE Greenhouse gases	The greenhouse effect is the **phenomenon** *whereby* the earth's *temperature rises* which is caused *by the presence* of **chemical compounds** in the earth's **atmosphere** *called greenhouse gases*, such as *water vapour, carbon dioxide, and methane*, which trap **short-wave infrared solar radiation**.	The greenhouse effect keeps the earth warm. This effect is caused by chemicals in the air that surrounds the planet which trap heat from the sun.
[insert your chosen scientific concepts here]		
[insert your chosen scientific concepts here]		
[insert your chosen scientific concepts here]		

APPENDIX 3. STUDENT SURVEY TO ASSESS SELF-REPORTED STUDENT LEARNING GAINS ON SCIENCE COMMUNICATION SKILLS

Please take a few minutes to answer the following questions on the activities you have completed in the communication activities.

Please take a minute to write down what you felt were the main skills you learnt in the communication activities.

For the questions below please tick the most appropriate box.

	Not at all	A little	Some what	Quite a lot	Very much
Did you **enjoy** these communication activities?					
How **relevant** do you feel these class activities are to your assignment?					
How **valuable** do you believe these communication skills will be to your career in science?					

As a result of these activities, how much do you think your ability to do the following things has improved?

	Not at all	A little	Some what	Quite a lot	Very much
… ability to identify and analyse a target audience					
… ability to use appropriate language to communicate science					
… ability to consider prior knowledge in an audience					
… ability to separate essential from non-essential content					
… ability to consider the social/political/cultural context of a scientific issue					
… ability to identify the purpose and outcome of a communication					
… ability to use style elements such as analogy, metaphor, and simile					
… ability to visualize data effectively					

	Not at all	A little	Some what	Quite a lot	Very much
Do you feel more **confident** in *effectively communicating science to a non-scientific audience* as a result of these activities?					

APPENDIX 4 MARKING CRITERIA USED TO EVALUATE STUDENT PERFORMANCE ON SCIENCE COMMUNICATION SKILLS

	Grade	7 – Outstanding (no faults)	6 – Excellent (minor faults that are easily fixed)	5 – Good (minor faults that need some work)	4 – Poor (many faults that need extensive work)	3-1 – Fail (all skills absent)
Criterion	Subcategory					
1) Identify a suitable target audience	NA	Audience is clearly identified and highly suitable and relevant.	Audience is clearly identified and suitable but could have been more relevant.	Audience is identified but this could have been done more clearly. Audience could have been more suitable and relevant.	Consideration has been given to audience but this is not clearly identified. Audience could have been much more suitable and is not particularly relevant.	No consideration given to audience.
2) Use language that is appropriate for the target audience	NA	All language is suitable for the target audience.	5% of the language is unsuitable for audience.	5-20% of the language is unsuitable for audience.	20-50% of the language is unsuitable for audience.	More than 50 % of the language is unsuitable for audience.
3) Purpose and outcome	3A) Purpose of the communication is clear	The purpose of the communication is made exceptionally clear.	The purpose of the communication is made clear.	The purpose of the communication is present but needs clarity.	The purpose of the communication is not clear.	No clear purpose.
	3B) The outcome is achieved effectively	Student achieves a highly effective outcome which aligns directly with the purpose.	Student achieves an effective outcome which aligns with the purpose.	The outcome could have been more effectively achieved and only indirectly aligns with the purpose.	The outcome is ineffective and does not align with the purpose.	No clear outcome.
4) Consider the levels	NA	All concepts used are appropriate for and can be understood by audience.	Most concepts used are appropriate for and can be understood by audience.	Some concepts used are appropriate for and can be understood by audience.	Few concepts used can be understood by audience.	None of the concepts can be

of prior knowledge in the target audience						understood by audience.
5) Consider the social, political, and cultural context of the scientific information	5A) Stakeholder identification and relevance	The stakeholders are • clearly identified, • highly relevant to the scientific issue.	The stakeholders are • identified, • relevant to the scientific issue.	The stakeholders are • identified but could have been more relevant to the scientific issue.	The stakeholders are • not clearly identified • and could have been more relevant to the scientific issue.	No relevant stakeholders identified.
	5B) Representative of the main social, political or cultural issues	Highly representative of the all main social, political, or cultural issues.	Representative of most of the main social, political, or cultural issues.	Representative of some of the main social, political, or cultural issues.	Representative of a few of the main social, political, or cultural issues.	Stakeholders do not represent the main social, political, or cultural issues.
6) Use appropriate stylistic element that is relevant to the audience	6A) Infographic or diagram	Diagram used is • relevant to format of publication, • content and message is very clear, • has high aesthetic	Diagram used is • relevant to format of publication, • content and message is clear, • has aesthetic impact,	Diagram used is • somewhat relevant to format of publication but could have been better chosen, • content and	Diagram used is • not really relevant to format of publication, • content and message require a lot more clarity,	Diagram used is not relevant to format of publication and no thought has been given

		impact, • all elements of the diagram are relevant, clear, and appealing to the audience.	• the majority of the elements of the diagram are relevant, clear, and appealing to the audience.	message require more clarity, • has some aesthetic impact, • the majority of the elements of the diagram are relevant, clear, and appealing to the audience but this could be improved.	• has little aesthetic impact, • the majority of the elements of the diagram are not relevant, clear, and appealing to the audience.	to impact, clarity, or appeal.
	6B) Analogy, simile, or metaphor	The element chosen is • suitable for the content, • relevant to the audience, • conveys the information clearly • greatly enhances the explanation by making the science simple and easy to understand and relate to, • no excess information/confusion.	The element chosen is • suitable for the content, • mostly relevant to the audience, • conveys the information clearly • enhances the explanation by making the science simple and easy to understand and relate to, • only minor excess information/confusion.	The element chosen • could have been more suitable for the content, • is mostly relevant to the audience, • conveys the information but could have been clearer, • is only partially relevant to audience., • displayed some excess information/confusion.	The element chosen • could have been more suitable for the content, • was not relevant to the audience, • conveys the information but does not simplify the concept due to excess information/confusion.	The element chosen was not suitable, clear, or relevant, and creates confusion.

7) Separate essential from non-essential factual content in a context that is relevant to the target audience		Communication only contains essential content and effectively enhances the audiences' understanding of the science.	Communication contains mostly essential content and enhances the audience's understanding of the science.	Communication contains some essential content and but also includes content that is irrelevant which may confuse audience.	Communication is dominated by non-essential content which is confusing for the audience.	All essential content is missing.

APPENDIX 5 SEMI-STRUCTURED INTERVIEW QUESTIONS FOR ACADEMIC COURSE COORDINATORS

1. Tell me about your overall impressions about the learning activity.
2. In your opinion, how clear or explicit was the teaching of these communication skills?
3. Do you see the skills taught as being useful and relevant in helping students to complete the assignment to a high standard?
4. What were your impressions about how the students dealt with the communication content being taught?
5. If provided with all the written resources, would you feel comfortable teaching this activity in subsequent years on your own?
6. Would you feel comfortable encouraging or mentoring other teaching academics to implement similar activities in their courses?
7. Are there any changes you would recommend to improve the teaching of these skills?
8. Did you notice any tangible differences in the quality of the communication component of the assessment pieces from this year compared to previous years? *(Asked in follow up interview following the completion of assessment marking.)*