The Interplay Between Science Engagement and Science Education

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Abstract

Through my experience as a postgraduate demonstrator, I have seen that teaching and public engagement are very similar practices; both require the sharing of knowledge and experience and the realisation of benefit. These two practices are often treated as distinct, with little wisdom shared between different practitioners, despite the recent move in education towards engagement-based values. To address this, I focused on implementing pedagogical tools in a series of public engagement sessions that took place online due to COVID-19. These comprised of school talks to students considering studying science at university, with the aim of introducing them to lecture-style classes and active research. My perspectives as a postgraduate during the delivery of these sessions allowed me to identify important or obscure parts of these topics that would be relevant to my audience, and how best to introduce them. Additionally, as a postgraduate researcher, I was able to approach my audiences as a peer, rather than a 'teacher', and encourage more successful engagement. I used several tools such as the BOPPPS (bridge-in, objectives, pre-test, participatory learning activity, post-test, and summary) model for lesson design and took advantage of the online setting through quizzes. These were effective, resulting in an engaged audience and 94% of the students believing biophysics is an interesting area of research following the session when prior to the session 68% had not heard of it, as measured through quiz responses.

Introduction

Science education and science engagement are two sides of the same coin. Both are performed with the goal of providing students or the audience with skills, understanding and appreciation of scientific findings and processes. However, each of these are often viewed as discrete enterprises when it comes to actual education or engagement practice, perhaps due to the relatively modern acknowledgement of science communication and engagement as a discipline (Logan, 2001; Trench and Bucchi, 2010), or perhaps due to the perception of the different requirements needed for formal and informal education (Ainsworth and Eaton, 2010).

Formal education can be summarised as “intentional, organised and structured”, whereas informal and non-formal learning are typically seen as less intentional and not following a structured educational intervention, such as a curriculum (Ainsworth and Eaton, 2010: 10). The intentional and organised aspects of formal learning have led to the development of specific ideologies and techniques in science education. Similarly, the field of science engagement has developed its own set of conventions and theories that consider themselves to be distinct from teaching. This can be exemplified by the move away from the “deficit model” (i.e. that the audience is deficient in understanding and must have the information presented to them by an expert) and the adoption of the “dialogue model” (i.e. that the audience has pre-formed conceptions and ideas that can be supplemented by information from an expert, and that the audience can provide information to the expert) (Reincke et al., 2020).

Despite how each of these fields might be viewed, having worked in both and developed my own practices, I believe that considering these as two distinct activities does a disservice to both, particularly as in recent years, education is more explicitly valuing engaged and active learning. This shift in thinking requires innovation and creativity in the development and delivery of teaching activities and will be unfamiliar to some educators. However, pre-existing science engagement techniques could be used as a framework to achieve these educational aims. This illustrates that science education and engagement are united in their objectives and descriptions, which can be seen from the National Coordinating Centre for Public Engagement’s definition of public engagement:

> “Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit.” (National Co-ordinating Centre for Public Engagement, n.d.)

Many of the aspects of both pedagogy and science engagement should be adopted by practitioners of the other. For example, a formal understanding of how people learn and engage with material is essential for science communicators to meet their aims, and classroom techniques can be exploited to create a familiar environment for audiences. On the other side, there are a wealth of ways in which engagement practices enhance teaching; through promoting creativity, demonstrations and considering the audience’s response and interest in the subject.

Through blending my understanding and experience in both of these areas, I developed an innovative strategy to approach and deliver a series of educational sessions for prospective undergraduate students through the STEM outreach team at the University of Leeds. These sessions focused on the research area of my PhD, biophysics, which is where physics and chemistry techniques are applied to the study of biological systems. This case study describes and evaluates how I combined the strengths and limitations of both practices at every stage of the project, to provide a successful learning intervention for 6 classes of students, which can hopefully be used to inspire practitioners in each of these fields to broaden their approaches.

Project Specifications

In my role as a postgraduate demonstrator, I was invited to plan and perform a number of learning activities through STEM@Leeds, the STEM outreach team at the University of Leeds. The primary activities for this case study were aimed at A-Level students considering Higher Education study to introduce them to university-style teaching and an area of active research. These activities were scheduled to be hour long online sessions due to the COVID-19 pandemic. I worked with the organisations Generating Genius, which supports BAME students pursue STEM careers, and In2Science, which promotes social mobility and diversity in STEM, and Huntington High School, York.

At A-Level, students do not necessarily study all scientific subjects. However, if they studied biology, they should be familiar with the concepts of cells and their structure, including membranes, and proteins and their role as enzymes. In chemistry, their knowledge should cover the structure of amino acids and their physics education should have introduced them to Newton's laws of motion, including dynamics and energy (Department for Education, 2014), all of which are important for understanding the content of the biophysics material I would be teaching them.

Here, I will discuss how each stage of developing and delivering pedagogical or public engagement activities is approached in education and engagement contexts to highlight their differences or similarities, and how I have unified them to achieve a combined method for aim and objective mapping, session planning, activity delivery, assessment, and evaluation.

Generally, the planning of public engagement and teaching activities follows a similar path of defining the aims, aligning these to specific objectives and then developing activities to meet the objectives through engaging different levels of knowledge and enquiry (Hundey et al., 2016; Wolf, 2007). However, in my own exposure to science communication, there has been less emphasis on using scholarship and theory to guide the planning of activities or mapping of objectives. Instead, rubrics such as the General Impact Framework (Kuruvilla et al., 2006) are commonly used, which focus on the broad impact types, such as "conceptual" (i.e. communicating scientific meaning and concepts), "instrumental" (i.e. influencing policy) and "capacity building" (i.e. altering behaviour and teaching skills), matched to outcomes such as "inspiring wonder", "provoking challenge" or "empowering" the intended audience. Although teaching objectives can fall into the same framework as this, there tends to be a more extended process for aim and objective development, as outlined by Moon (2002). The aim provided to me by STEM@Leeds was to introduce the students to research-based teaching, and so I translated this aim into two objectives: to introduce the students to university-style lecturing and an area of active research they may not be familiar with. In terms of public engagement outcomes, this covered both 'conceptual' and 'capacity building' impacts, in that I aimed to articulate scientific concepts and methods to them and teach them skills need for university-style lectures, with the overall hope of leading them towards higher education.

Session Planning

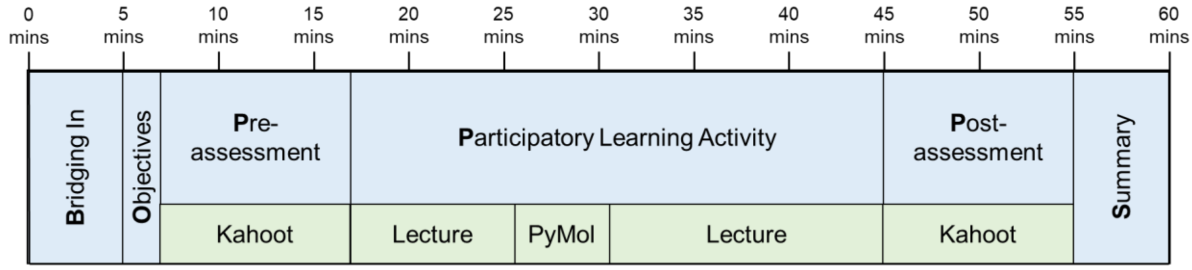

Figure 1. The Session Outline as Developed Using the BOPPPS Model. The order and timings of the sections of the BOPPPS model (light blue) alongside the digital component the students interacted with (light green).

Session design can differ substantially between outreach and educational activities, as outreach activities can have many different formats which are not necessarily experienced simultaneously by each audience member. For example, events I have contributed to through Pint of Science, an international science festival that brings science to informal settings, can involve multiple talks with ‘free time’ between them to engage in science-based games, or ‘carousel-based’ formats where the audience moves from stall to stall as at science festivals. Traditionally, teaching tends to rely on moving through the subject matter together to cover the content and ensure all the objectives are met, although the move to online teaching has allowed more exploration of asynchronous learning (Brady and Pradhan, 2020), albeit typically with a pre-determined order of content.

To unite these different aspects, I chose to use the BOPPPS model to structure my sessions (Pattison and Day, 2006). The BOPPPS model consists of bridging into the topic area, outlining the objectives of the session, a pre-test, followed by a participatory learning activity, a post-test and a summary section (Pattison and Day, 2006) (Fig. 1). I felt that this choice was a creative way of merging education and engagement while maintaining the best aspects of each. The sequential tasks allow for the educational journey to be preserved, whereas the division of the session into specific tasks and activities allows students to opt in and out of certain elements then join as the next activity starts, much like a science engagement activity. Additionally, as this was screen-based work and the attention span for this format is much shorter than in traditional classroom environments (Brame, 2016), I hoped that adopting a model that lends itself to multiple shorter sequential activities would keep the students engaged throughout the session.

Activities

‘Bridging into’ the topic is a term used in educational contexts but despite not often being explicitly named, it is a concept not uncommon in science engagement practice. Understanding the pre-existing knowledge of the audience is essential for engaging them and identifying any misconceptions the person delivering the session might be able to address. Biophysics is not taught at A-level, or typically at undergraduate level. Bridging into the area from physics and biology helped the students engage with what might have otherwise been an unfamiliar subject. Although this research may not have been of particular interest for all students, I explained that during courses you might be exposed to different topics and need to be able to extract the relevant information. Much like in other outreach activities, I saw that bridging in led to increased confidence in the students, as they asked insightful questions rather than assuming they had no underlying knowledge.

An innovative part of my session design was the use of Kahoot! quizzes to bridge into the biophysics topic area, perform the assessments and evaluate whether the objectives were met. Kahoot! is a game-based learning platform where students join a pre-designed quiz consisting of multiple choice, free-typing, puzzle, polling and word-cloud questions (Licorish et al., 2018; Wang and Tahir, 2020). These questions can be summative (i.e., give the student points and be marked right or wrong), or formative (i.e., provide information to the group and educator). Alongside the correct choice, the speed of the answer can contribute to the students' ranking on an anonymised scoreboard. I chose to use Kahoot! as the use of gamification is increasing in education (Dichev and Dicheva, 2017), and can engage students with an unfamiliar topic and motivate them to pay attention throughout the session (Licorish et al., 2018; Wang and Tahir, 2020). I designed each of the two Kahoot! quizzes to have up to 5 questions with a mixture of formats and topics covered in the session (Table 1). This activity was very well received by the students and the results are discussed in the evaluation section of this case study.

Pre-assessment			
Question	**Question type**	**Answers (correct in bold)**	**Aligned skill from Bloom's taxonomy**
Where are you from?	Free typing	-	-
What is your favourite science subject at school?	Poll	Biology	-
		Chemistry	
		Physics	
		Maths	
What does *E. coli* stand for?	Multiple choice	**Escherichia coli**	-
		Ewwww coli	
		Esherricha coli	
		Elegans coli	
Who discovered what DNA looks like?	Multiple Choice	Holmes and Watson	-
		Watson and Crick and Franklin	
		Dorothy Hodgkin	
		Jiminy Cricket	
What do you think of "biophysics"?	Free typing	-	-
Post-assessment			

Question	Question type	Answers (correct in bold)	Aligned skill from Bloom's taxonomy
Which of these isn't a potential way of using this research technique?	Multiple choice	**Studying slow cellular processes**	Remember and understand
		Developing drugs	
		Predicting protein properties	
		Studying solutions and mixtures	
How would you set up a membrane protein simulation?	Drag and drop ordering	1. Take the protein coordinates 2. Add water, salt and lipids 3. Apply Newton's laws of motion 4. Mix in a supercomputer	Remember and apply
Which of these should be a researcher priority?	Poll	Malaria, as it is the most deadly	Analyse and evaluate
		Toxoplasmosis, as it is the most widespread	
		Leishmaniasis, as it can take years to heal from even mild forms	
		Trypanosomiasis, as infection of livestock can impact food security	
What do you think of "biophysics"?	Free typing	-	-

Participatory Learning Activity

The learning activity was initially a lecture delivered through screen-sharing a PowerPoint, with the option for students to ask questions throughout, either directly to me or in the general chat feature. This was made up of an introduction to myself and my journey into higher education, an introduction to biophysics drawing on biology and physics concepts from secondary school education, followed by an example of one of my research findings. Here was where the interplay between science education and engagement was very instrumental, as often lectures are designed to get across the necessary information and act as a resource for further solo study. In this instance, however, the students would not be required to review the information at a later date, therefore more science communication style strategies could be used, as described below, which could be applied to other lectures and topics.

Story-telling techniques are an incredibly useful technique in science engagement, as they have been shown to increase the retention of scientific detail and concepts (Dahlstrom, 2014), as well as create a rapport between the audience and the presenter (Riedlinger et al., 2019). I used these techniques throughout my talk to introduce detail and obstacles, as well as keep the information in a clear narrative. For instance, rather than describe the progress of the research project I worked on, I framed myself as the central character and described my feelings, experiences and personal progress through the projects using a narrative arc (Joubert et al., 2019). This is novel in educational settings, as the relationship between the presenter and the audience is often not as well explored, and there is often less emphasis on two-way communication (Ainsworth and Eaton, 2010). However, establishing and maintaining a rapport, for instance through personal stories, is essential for engagement as the barrier between a supposed expert and the audience is reduced (Maddalena and Reilly, 2018). I used this style throughout my learning activity. When discussing more abstract findings, I used analogies where the components were framed in narrative style, for example casting specific proteins as protagonists, antagonists, or helpers to provide a different style of content delivery.

After running this activity for the first time, I realised the central "participatory learning activity" was too long as attention in the students reduced and the scores in the quiz questions on the later topics were lower. Therefore, I modified my materials and plan for the later sessions by introducing a section in the middle of the lecture where I changed computer programmes to PyMol (DeLano, 2002) and explored a 3D protein structure with the students to maintain engagement. I also modified some of my slides to keep them accessible. This improved the quiz answers and I saw increased communication in the chat, indicating maintained attention.

Assessment

Assessment is a major component of education as the majority of formal learning interventions are in preparation for examination of the students' knowledge (Ainsworth and Eaton, 2010). Although not every assessment is summative and leads to a grade or qualification, every test is useful for students to understand their attainment and receive feedback on how to improve. As feedback is a cornerstone of education, it was easy to draw on the extensive research into assessment and feedback principles to shape these sessions (Sadler, 1989; Voelkel et al., 2020). However, in science engagement, assessment of the audience's understanding is very rare as the intended impacts do not encompass gaining specific understanding, and so there is minimal assessment-based scholarship to draw on. The assessment of this session fell more into engagement-based needs, as there is no final summative exam. Rather, I wanted to understand whether the session had effectively introduced the students to university-style lectures and an area of active research. Therefore, a true blending of approaches could take place, including education-based assessment and feedback techniques, but 'disguising' these in a fun and engaging format that felt more enjoyable than formal assessment.

In this work, the primary mode of assessment was embedded into the Kahoot! quizzes. These were particularly valuable in this kind of session as they are quick and provide instant correct or incorrect feedback and an indication of how many of their peers answered similarly. As the majority of the questions were multiple-choice, it initially seemed that it would be difficult to assess the higher order skills in the students as defined by Bloom's taxonomy (apply, analyse, evaluate, create) (Bloom et al., 1956). However, I followed the work of Atkinson and Meadows (2018) and wrote my questions to assess higher order skills through a mixture of question types (Table 1). Firstly, using scenario-based question stems, such as "how would you put together a membrane protein simulation?" so the students needed to apply their biology knowledge and remember simulation details. Secondly, I used data-based questions where I provided disease prevalence and mortality data and asked which could be a highest research priority. To answer this question, the students had to analyse the data and evaluate the reason for priority. Their response to these questions was positive, and it guided some of their later discussion about long-term research impact.

Evaluation

Both science communication and education rely heavily on evaluation to assess how well the objectives and aims of the sessions have been met. Traditionally, these take the form of feedback sheets and surveys with the option of feedback (Ziegler et al., 2021). However, these methods often have a low uptake and return rate compared to the number of individuals who have engaged in it (Jones et al., 2013). This can be detrimental to the continued development of the session, as it can lead to overrepresentation of a limited number of viewpoints. I somewhat overcame this by embedding the evaluation into the online quiz. Many of the aspects that make Kahoot! a good assessment platform are also valuable for evaluation, for example, through the use of anonymity. In the pre- and post-tests, I used free-typing questions to ask what the students thought of biophysics to evaluate whether I had met my objective of introducing them to a current research-area. I also used the results from the quiz questions to gauge if the information was presented well enough to allow the students to get the right answers.

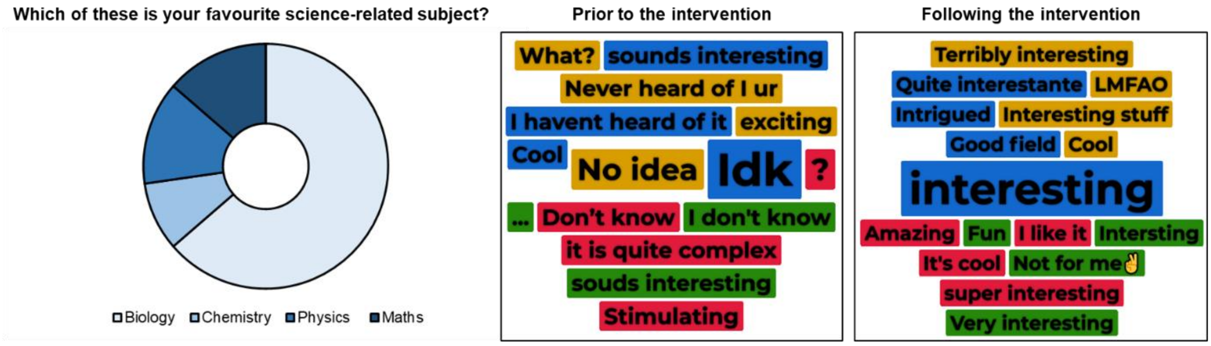

Figure 2. The Opinions of the Students on Different Science Subjects. Kahoot! was used to ask the students which their favourite science-related subject was using a poll style question, and their responses to a free-typing question asking their thoughts on biophysics as a research area before and after the session were recorded and intended for thematic analysis.

The free typing questions with the prompt of "what do you think of biophysics?" were intended for thematic analysis, but there was a large amount of consistency in the results, so quantitative analysis methods were used. The responses showed that 68% of the students had not heard of biophysics prior to the session. Comparatively, 94% of the students indicated that they thought biophysics was an interesting area of research following the lecture (Fig. 2). This was particularly remarkable, as prior to the session, only 13.6% of the students indicated that physics was their favourite science-related subject (13.6% maths, 9.1% chemistry and 63.6% biology), and therefore I did not anticipate that so many would be engaged by the material. Understanding the interests of the students may have been an integral part of this success as I was able to tailor my delivery to the majority of the students by emphasising the biological aspects of the research once I knew that the majority favoured this subject. This is another area from which education practice can learn from science engagement as it is typically guided by the interests of the audience as opposed to the objectives.

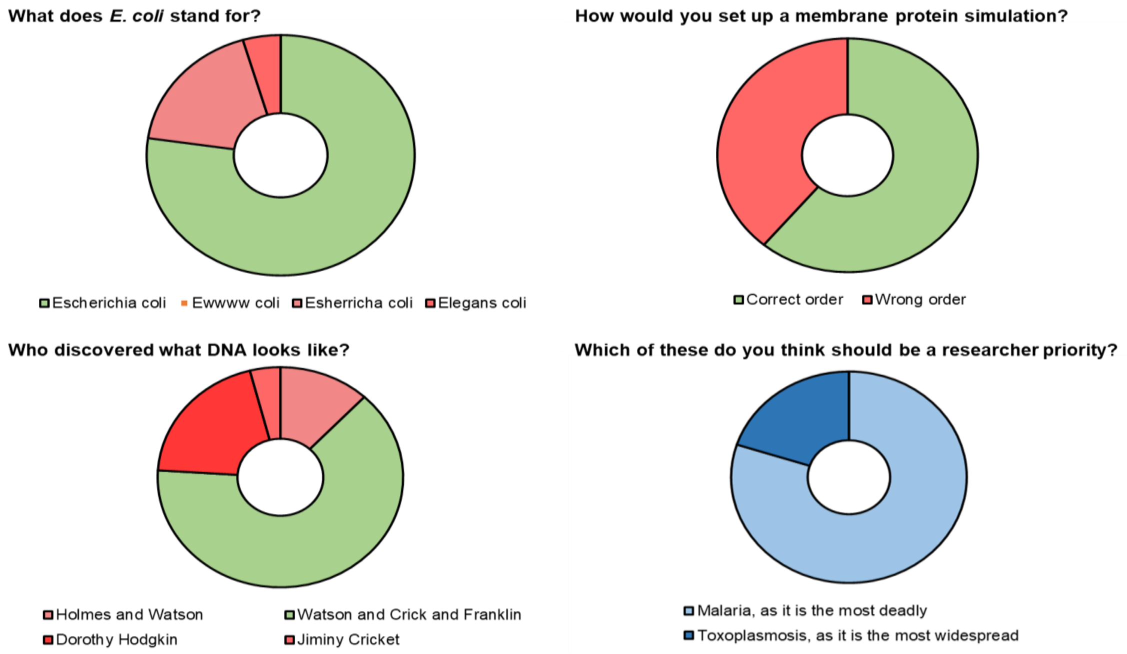

Figure 3. The Results of the Post-Assessment Questions. Kahoot! was used to assess the students following the participatory learning activity. The green regions on the right-hand side of the graphs are used to indicate a correct response from the students, whereas red is used for incorrect answers. Blue is used for informative rather than summative questions.

The assessment of the students also allowed further evaluation of the session (Fig. 3), as their attainment indicated what topics and skills were the best understood by the students. The questions “what does E. coli stand for?” and “who discovered what DNA looks like?” assessed the understanding and remembering skills of the students. The attainment was very high for these questions with 77.3% of students picking Escherichia coli and 64% selecting Watson, Crick and Franklin. However, these are topics that are likely to be covered during their schooling and so it isn’t clear if these high marks were due to my instruction or prior knowledge. The question “how would you set up a membrane protein simulation?” relied on knowledge gained from my session. That 61.1% of students answered correctly indicates that they remembered details and were able to apply them to the situation posed in the question. The success rate of this question was lower than the prior two which may be due to the unfamiliar content and the higher-order skills being assessed, but the high attainment indicates that students were able to engage with the new information presented to them. Finally, the question “which of these do you think should be a researcher priority?” assessed the students evaluating and applying skills as they had to interpret mortality and prevalence data and the reasoning presented to them. This was not marked “right” or “wrong” as all the options were subjective, but it was interesting to see the mortality be rated as a higher priority than prevalence, which was used to inform future sessions to focus the materials and content on the biological relevance of the topic area.

Limitations

These findings demonstrate how engagement techniques can be combined with educational practice to achieve module outcomes, while prioritising the interests of the students. However, this evaluation strategy was limited as it was primarily quantitative and so did not provide me with substantial understanding of the student’s thoughts and experience of the session. Additionally, the qualitative information from the free-typing questions were not particularly detailed, either due to lack of specificity in responses or short answers from the students. Therefore, it is difficult to understand which activities or topics were most engaging or which could be improved and which strategies were most useful for the students. For a better understanding of most engaging activities and topics, and of most useful strategies for students, free-typing questions might not be the best ways to get feedback. More structured questions would be more effective for this purpose. Additionally, the limited access to students from external institutions and the limited number of attendees meant reduced opportunities to follow up on any of the insights from the feedback with the students. In future, when applied to undergraduate students of my own institution, the strategy used in this work will be adapted by taking a mixed methods approach to enhance the qualitative data collection, perhaps through combining focus groups or interviews and the in-session feedback.

Concluding thoughts

The integration of science education and engagement practices is an emerging, yet successful strategy for the planning, delivery, assessment, and evaluation of teaching sessions. Incorporating aspects of both, from more structured and scholarship-based elements of pedagogical practice alongside the more flexible, informal techniques used in science communication, led to teaching interventions that were simultaneously engaging and interesting for students, while equipping them with higher-order skills and information for their subject area. Although these sessions were held with A-level aged students, these techniques could be applicable in other educational settings and I hope that these findings encourage others looking for ways to expand their practice into more engagement-focused teaching approaches.

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