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Student-Produced Video of Role-Plays on Topics in Cell Biology and Biochemistry: A Novel Undergraduate Group Work Exercise

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Group role-plays are an excellent form of collaborative learning but are not widely used in the teaching of core scientific concepts at undergraduate level. I describe here an example of group role-plays being used to explore fundamental processes in cell biology, including vesicular trafficking, cell migration, cell division, endocytosis and the targeting of proteins to subcellular organelles. The students are cast in the roles of the key proteins involved in a particular process by the instructor, but groups are then given a free rein to develop a role-play that illustrates the process. The role-plays produced can be classified as analogy role-plays and choreographed or animated demonstrations. Videoing of the role-plays allows each group's work to be shared with the class as a whole, with the videos proving useful as a revision aids leading up to the terminal exam. Templates for role-plays on eight core topics in cell biology and a model for peer input into the grading of individuals within groups are provided. The advantages of videoing the role-plays from both an instructor and student point of view are discussed. Student feedback supports the value of the role-play exercise in (1) encouraging scientific discussion, (2) promoting teamwork skills and self-awareness and (3) helping students, especially those visiting from abroad, to integrate with fellow classmates. These observations make the case that videoed role-plays, in which students play the roles of molecules, proteins, organelles or cell types, represent a potentially valuable form of collaborative learning in the cell and molecular life sciences.

Keywords: video, role—playing, cell biology, group work, collaborative learning, graduate attributes

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INTRODUCTION

Group work or cooperative learning is a form of active learning that has potential benefits that extend beyond just being an alternative or improved way of learning course material. For example, Shimazoe and Aldrich (2010) identified six proposed benefits of active learning to students, namely (1) promoting deep learning, (2) helping students earn higher grades, (3) teaching social skills and civic values, (4) teaching higher order thinking skills, (5) promoting personal growth, and (6) developing positive attitudes toward autonomous learning. Notably, several of these benefits relate more to personal development and generic skills than to the learning of the specific topic at hand. Role-playing is an established form of cooperative learning, and there is evidence for the effectiveness of role-plays both in achieving learning outcomes (McSharry and Jones, 2000; Craciun, 2010; Yang et al., 2010; Azman et al., 2018; Latif et al., 2018) but also in developing

desirable graduate attributes such as teamwork, communication and problem solving skills [4]. The importance of such skills is widely touted by employers of science graduates, sometimes more so than discipline-specific knowledge, arguing in favor of the incorporation of role-plays and other forms of cooperative learning into undergraduate science curricula.

It is probably safe to say that role-playing is not as widely used in the sciences as it is in other academic disciplines, although quantitative data in this regard is scarce. Infrequent use of role-playing in science education likely stems from the simple fact that disciplines such as social sciences, humanities, business and law are centered around humans and human activities. Thus, learning scenarios for role-plays in which students play the roles of people come to mind in a natural and relatively obvious way. In areas such as medicine and health it is also quite straight forward to formulate role-play scenarios that mimic practitioner: patient interactions and indeed these are widely used as both learning and assessment tools (Knowles et al., 2001; Joyner and Young, 2006; Luttenberger et al., 2014; Vizeshfar et al., 2019). By contrast, in science the most obvious role-play scenarios in which students play the roles of people might be in examining historical figures at the center of famous scientific discoveries or debates (Tippins et al., 1993; Odegaard, 2003; Cakici and Bayir, 2012). In addition, role-plays fit well at the interface between science and other discipline when exploring ethical (Carvin and Stefani, 1993; Brummel et al., 2010; Agell et al., 2015; Siani and Siani, 2019), environmental (Smith et al., 2005), or commercial (Chuck, 2011) implications of scientific discoveries.

However, to apply role-play to core topics in science or mathematics the roles that must be played are not those of people but rather of things like particles, forces, elements, atoms, numbers, laws, equations, molecules, cells, organs and so on. The learning scenarios for science-based role-plays in which the characters represented are not people are less obvious, probably explaining why the use of role-plays in science education is less common. Nevertheless, some examples of such role-plays can be found in the science education literature. Focusing on the life sciences, role-plays in which the characters are the organelles in a cell (Cherif et al., 2016), the enzymes or molecules involved in fundamental cellular processes like DNA replication, RNA transcription and protein translation (Takemura and Kurabayashi, 2014; Geraedts et al., 2019) or the atoms and molecules in metabolic pathways such as glycolysis and the Krebs cycle (Takemura and Kurabayashi, 2014; Cherif et al., 2016) have been described for example. In addition, some scholars have developed props/kits/models that enable role-plays of a type that Geraedts et al. (2019) term "embodied simulations" of concepts like genes, alleles and inheritance (Pashley, 1994), natural selection (Petersen and Petersen, 2017) and DNA replication and methylation (Geraedts et al., 2019). To my knowledge however, the use of role-plays in the teaching of advanced core scientific concepts in the areas of cell biology and biochemistry at 3rd or 4th year undergraduate level has not been described in the literature.

PEDAGOGICAL FRAMEWORK

The potential value of role-plays in science education is well-recognized (McSharry and Jones, 2000; Odegaard, 2003; Dorion, 2009; Craciun, 2010). McSharry and Jones (2000) summarized the potential value of role-plays as an education tool in science. Amongst other things, they highlighted that role-plays can: (1) give students a feeling of "ownership" of their education, (2) give students a chance to experience topics in a physical way which may be more appropriate to their personal learning style and (3) promote analogies that help students to conceptualize and increase learning. These benefits would apply to science teaching at all levels, however, much of the literature on role-plays in science education focuses on primary or high school teaching. The widespread use of role-plays in undergraduate science has not been realized, possibly because the scenarios in which they can be applied in specific scientific disciplines require more thought and effort to construct. The communication of discipline-specific templates and successful models for the application of role-playing in science education is thus crucial to encourage their wider adoption. Here I describe a group role-play assignment that has been developed over a 10-year period of reflective teaching practice in an introductory cell biology course at undergraduate level at an Irish University. The most recent refinement of the assignment was to have students produce videos of their role-plays—a development which was perceived positively by both students and instructor. I provide templates for role-plays based on eight fundamental topics in cell biology and suggest that this model of videoed group role-plays is a useful cooperative learning format that will allow learners to apply their varied creativity and talents to exploring and explaining diverse scientific topics while simultaneously developing their teamwork and associated skills.

LEARNING ENVIRONMENT

The context of this case study is a 3rd year undergraduate course entitled *Introduction to Cell Biology and Biomembranes (BC3003)*, a core module for students in the 4-year BSc in Biochemistry degree at University College Cork, Ireland. These students would have just chosen to specialize in Biochemistry as their final degree outlet having spent 2 years in the much larger and broader Biological and Chemical Sciences class group. The course is also available to suitably qualified visiting students. In the 2018/2019 academic year thirty nine Irish BSc Biochemistry students (26 female, 13 male) and seven visiting students (from China, The Netherlands, Spain and The United States of America; 5 female, 2 male) were registered for the course.

The course consists of 18 h of lectures, a 2-h tutorial and 8 h of laboratory classes across a 6-week period in the first half of the first semester. Assessment for the course is based on laboratory performance (10%), continuous assessment (10%) and an end-of-semester written examination comprising of multiple choice and short essay style questions (80%). The group role-play assignment described here is the major continuous assessment element, accounting for 7% of the overall module marks. The course learning outcomes relevant to the group

role-play assignment state that on successful completion of the course, students should be able to: (1) Describe the organization and functions of membranes and organelles in eukaryotic cells, (2) Discuss the role of the different cytoskeletal elements in a variety of cell types, (3) Compare the mechanisms by which newly synthesized proteins are targeted to the major organelles in eukaryotic cells, (4) Illustrate how proteins are trafficked within the secretory and endocytic pathways. The role-plays described here focus on the cytoskeleton, protein targeting and vesicular trafficking—cell biology phenomena that seem well suited to role-playing given that they are dynamic processes involving communication and interactions between a small number of key proteins and/or subcellular compartments which can be represented as the characters in a role-play.

RESULTS

A Videoed Group Role-Play Assignment

The model for a videoed group role-play evolved over a number of years of teaching this course. It began as in-class demonstrations for a couple of topics in the course with the instructor providing a few simple props (paper bags, rope, a scissors) and asking students to volunteer to come to the front of the class to demonstrate a process such as the targeting of secreted or transmembrane proteins to the endoplasmic reticulum. In this case a rope being pulled out of a bag represented a nascent polypeptide emerging from the ribosome with the scissors cleaving the signal sequence from the polypeptide as it entered the endoplasmic reticulum (ER). It was apparent that certain key concepts could be explained more clearly using this demonstration compared to explaining a textbook figure as part of the lecture. It was then decided to develop these demonstrations into a group work assignment that would be graded as a continuous assessment component of the course. For this small groups of students were assigned a specific cellular process and each group member was cast by the instructor as a protein or protein complex involved in that process. Each group member researches their own protein/protein complex and posts a short description of its function to a group discussion board using the Blackboard virtual learning environment. The groups then meet outside of regular class hours to develop and rehearse a role-play based on their assigned cellular process. Two hours of class time were then given over for the performance of the role-plays from the six different groups in front of the rest of the class, with some discussion of each topic. The most recent step in the evolution of this assignment, taken this year, was to ask the groups to produce a video of their role-play rather than having them perform it live in front of the class. This format for the role-play had several advantages from both the student and instructor perspective that are discussed later.

TABLE 1 | Casting of students in the roles of proteins/protein complexes for role-plays about fundamental cell biological processes.

Topic 1:	**Protein transport from the ER to the lysosome**	**Topic 2:**	**Protein targeting to the ER**	**Topic 3:**	**Nuclear import of proteins**
Student #	**Role**	**Student #**	**Role**	**Student #**	**Role**
1	α-Galactosidase A [cargo for transport]	1	Insulin [cargo for translocation]	1	p53 [cargo for nuclear import]
2	Oligosaccharyl transferase (in the ER)	2	Signal recognition particle (SRP)	2	Nuclear pore complex
3	N-acetylglucosamine phosphotransferase	3	SRP receptor	3	Ran / Ran GTPase
4	Phosphodiesterase	4	Sec61 / Translocon	4	Importin β
5	Mannose-6-phosphate (M6P) receptor	5	Ribosome	5	NTF2 (nuclear transport factor 2)
6	Adapter protein 1 (AP1)	6	Signal peptidase	6	Ran-GEF (Guanine nucleotide exchange factor)
7	Clathrin	7	Chaperone protein (in the ER)	7	Ran-GAP (GTPase activating protein)
Topic 4:	**Protein targeting to the mitochondrial matrix**	**Topic 5:**	**Vesiclular trafficking from the ER to the Golgi ER-Golgi**	**Topic 6:**	**Receptor-mediated endocytosis**
Student #	**Role**	**Student #**	**Role**	**Student #**	**Role**
1	Isocitrate dehydrogenase subunit [cargo]	1	COP II (Coat protein II complex)	1	Transferrin [cargo 1]
2	Cytosolic Hsc70	2	Sar1 GTPase	2	Low density lipoprotein particle [cargo 2]
3	Mitochondrial Hsc70	3	Sec12	3	Clathrin
4	Tom 20/22 import receptor	4	Cargo Receptor	4	Adapter protein 2 (AP2)
5	Tom 40 import pore	5	Rab1	5	Dynamin
6	Tim44	6	Rab1 effector	6	V-class proton pump (in endosome)
7	Tim23/17	7	v-SNARE	7	LDL receptor
8	Matrix processing protease	8	t-SNARE	8	Transferrin Receptor

*Groups of seven or eight students were cast by the instructor in the roles of the major proteins/protein complexes involved in a particular cell biological process. In most cases these are processes involved in the targeting of proteins to a particular destination in the cell, with one of the characters being a representative cargo protein that must be transported to that subcellular location. These six topics were used in the 2018–2019 academic year. The casting for two additional role-play topics based around the cellular cytoskeleton is provided as Supplemental Material online (**Table S1**). ER, endoplasmic reticulum.*

In the 2018–2019 academic year the assignment involved six groups of 7–8 students with each group being assigned to a different topic (cellular process) that had already been covered during lectures (**Table 1**). Each student within the group was assigned the role of a particular protein or protein complex involved in the process. Assignment of students to groups was simply done alphabetically according to surname which resulted in the visiting students being intermixed with the Irish students. No attempt was made to cast particular students in particular roles. The groups then had a 2-week period to develop, rehearse and make a video recording of their role-play. This was done entirely outside of scheduled class time and the groups were given a very free rein as to how they approached the task. The role-plays were uploaded to the YouTube video hosting service as unlisted videos by the instructor (with the exception of one group who uploaded their video to their own account as a public video). The unlisted designation means that the video will not appear in searches on YouTube, only people who are given the link to the web address can find it. This provided a simple way to share videos with the entire class. Written consent was obtained from students to use the videos in this manner. The videos were played during class with a brief discussion of each topic before links to the videos were made available to the class.

Analysis of the Role-Plays Produced

Student groups were given a large degree of freedom to develop the concept for their role-play as they saw fit. The only stipulations were that all of the "characters" must be involved and that the role-play would accurately illustrate the assigned cellular process. It is not surprising then that the six groups developed very different styles of role-plays with unique concepts to represent their cellular processes (**Table 2**). McSharry and Jones (2000) identified seven overlapping categories of role-plays in the context of science teaching and learning, albeit more in a high school context. These categories are experiments/investigations, games, presentations, metaphorical role-play, analogy role-play, simulation (or moral/ethical role-play) and theater in education. According to this classification the role-plays developed here fall into the categories of presentations and analogy role-plays. This probably reflects the fact that these categories are best suited to the specific format of the assignment and does not mean that the other types of role-play could not be used to represent the assigned cell biology topics if students were given a different brief. Two groups used animation or drawing rather than physically acting out the role-play (**Figure 1**), with each group member then describing the role played by their protein in the cellular process using voice-over. Two groups described their assigned cellular processes using demonstrations in which students acted out their roles in the process with the aid of simple props like balloons, foam noodles, coats, back packs, rope. In one case a single student narrated the whole demonstration. In the other case each student introduced their character in advance and then the various steps in the demonstration of the process were labeled with text but were not narrated. Finally, two groups performed dramatized role-plays, making quite extensive analogies between the proteins/protein complexes/subcellular locations involved in their assigned process and the characters/locations in their role-play (**Table 3**).

Assessment of the Assignment

The grading of group-work assignments is fraught with difficulty (King and Behnke, 2005). It is generally desirable to assign individual marks to members of a group in a manner that rewards those who contribute most to the project. However, given the format of the assignment, the instructor had very limited insight into the contribution of individual group members, so a system of peer assessment was needed. Since the assignment is only worth 7% of the overall course grade a simple but fair system that is not

TABLE 2 | Categorization of role-plays.

Topic	Role-play style and concept	Location of video shoot	Description
Protein transport from the ER to the lysosome	Analogy/Drama: "The morning routine of a celebrity"	A student apartment	The enzymes and proteins involved in the process are represented by a chef, stylist, personal assistant etc. who help the celebrity prepare for the day. Hairstyling, breakfast represent post-translational modifications.
Protein targeting to the ER	Narrated stop-go animation using modeling clay and voice-over	On a table	Proteins represented by labeled shapes made of modeling clay. Paper of different colors used to depict cytoplasm, ER lumen and membrane.
Nuclear import of proteins	Narrated demonstration: students as proteins/protein complexes	On-campus recording studio	Students move through a ring made of foam swimming pool noodles representing the nuclear pore. Person holding balloons depicts Ran-GDP/GTP, with bursting of balloons indicating GTP hydrolysis.
Protein targeting to the mitochondrial matrix	Analogy/Drama: "Girl trying to get into "The Matrix" nightclub"	On-campus recording studio	The cargo protein is represented by a girl who must interact with other proteins (night club staff) in order to enter the mitochondrion (nightclub).
Vesicular trafficking from the ER to the Golgi	Choreographed demonstration: students as proteins/protein complexes	A basketball court	Students wearing coats represent coat proteins, 2/3 balloons depict GDP/GTP, cargo protein represented as a backpack. Step-by-step demonstration with text slides to highlight each stage of the process.
Receptor-mediated endocytosis	Sketching of the process with voice-over narration	On a whiteboard	One student draws the proteins and membranes involved in each step of the process on a whiteboard, while each student describes the role of their protein.

The style and concept for the role-plays are shown, along with the location of video shoot are indicated.

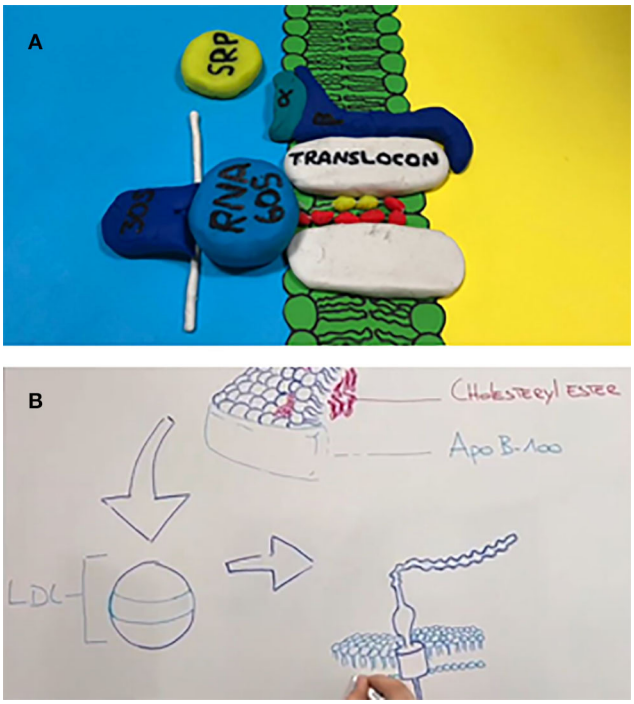

FIGURE 1 | Examples of role-plays that used narrated animation and drawing to explain the assigned cellular process. One group used stop–go animation with shapes made from modeling clay to illustrate protein targeting to the ER **(A)**, while another employed drawing on a white board to describe receptor-mediated endocytosis of low density lipoprotein (LDL) particles **(B)**. Both role-plays used voice-over narration to explain the processes.

too onerous or time consuming on the students was desirable. Based on these considerations a peer assessment system was developed that involves students distributing twelve votes among the seven or eight members of their group simply according to their impression of the contribution that they made to the project. A maximum of three votes can be given to any one person. You must use all your votes and you cannot vote for yourself. These rules prevent students from distributing their votes completely uniformly across the group; they must discriminate to some extent between group members in terms of their contribution. At the same time these rules mitigate against the effect of reciprocal voting pacts between students along the lines of "you vote for me and I'll vote for you." Thus, even if two students made a pact to vote for each other, they could only give each other at most 3 votes. With a group size of 7 or 8 students, and the rule that maximally 3 votes can be given to any one student, the votes of the other students in the group would largely negate the effect of such a pact between two students. It is highly unlikely that a student who did not contribute to the project would be able to persuade enough people in the group to vote for them in order to significantly elevate their tally of votes. A similar system was used to obtain student input regarding the role-plays of other groups. The voting form was an excel spreadsheet completed by each student from which the overall votes per individual and per group were tallied by the instructor. An example of a completed voting form as well as the excel file template are provided as **Supplemental Files S1**, **S2**.

TABLE 3 | Examples of the analogies made in two of the role-plays.

Protein/Organelle	Analogy
Topic 1: Protein transport from the ER to the lysosome "The morning routine of a celebrity"	
α-Galactosidase A [cargo for transport]	A celebrity
Oligosaccharyl transferase	Hairdresser
N-acetylglucosamine phosphotransferase	Chef
Phosphodiesterase	Cleaner
Mannose-6-phosphate (M6P) receptor	Stylist
Adapter protein 1 (AP1)	Personal Assistant
Clathrin	Bodyguard
Endoplasmic Reticulum	Bedroom
Cis-golgi	Kitchen
Trans-golgi	Living Room
Endosome	Lift
Lysosome	Car
Topic 4: Protein targeting to the mitochondrial matrix "Girl trying to get into 'The Matrix' nightclub"	
Isocitrate dehydrogenase subunit [cargo]	Girl on a night out
Cytosolic Hsc70	Her Friend
Mitochondrial Hsc70	Nightclub Staff
Tom 20/22 import receptor	Bouncer
Tom 40 import pore	Nightclub Staff
Tim44	Nightclub Staff
Tim23/17	Nightclub Staff
Matrix processing protease	Nightclub Staff
Cytosol	Outside the club
Mitochondrial Matrix	In the club

The overall concept and the analogies made between the proteins/protein complexes/subcellular locations and the characters/locations in the role-play are indicated. The video of the role-play for topic 1 employs elaborate analogies and can be viewed on YouTube at the following link: https://youtu.be/oxOBMQhVtT0.

It is clear from the results of the "within-group" voting that some individuals obtained consistently high votes from all other group members, presumably reflecting that they took on a leadership role or made a major contribution to the project (shown in **Figure 2**). In certain groups some students accumulated very few votes whereas in other groups the distribution was more even—presumably an indication of the degree of workload sharing in those groups. The input from the tallied "between-group" voting was considered by the instructor in assigning a mark to each group. In addition, the instructor evaluated each group and their role-play using an assessment rubric (**Supplemental File S3**). Individual marks were then assigned to each group member. The peer-assessment input was considered here, but so too were contributions to the group discussion board and whether the peer-input voting form had been completed (since those who don't complete the form would be advantaged by getting votes from team members but not giving anyone else their votes). The variation in marks for individuals within a group was limited to a range of ± 5% of the

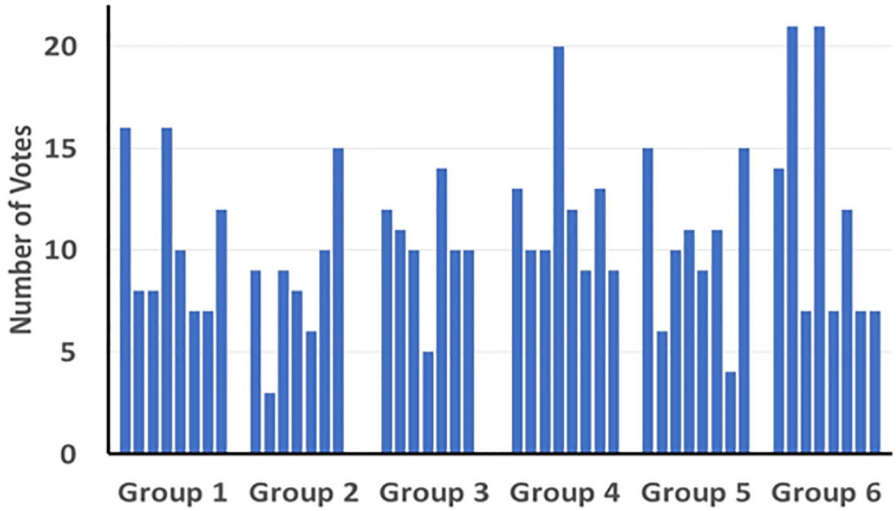

FIGURE 2 | Peer input into assessment: distribution of the total votes for individuals within groups. The total number of votes received by each individual from students within their own group is plotted. Students distributed their votes simply based on their feeling of how much other students contributed to the team effort. Note that the total number of votes cast per group differs because groups had either seven or eight members and not all students voted. Group numbers do not correspond to topic numbers in **Table 1** in order to preserve student anonymity.

group mark in such a way that the group mark was the average of the individual marks.

Student Feedback

Feedback on the assignment was obtained through an online survey using Google Forms (**Figure 3A**, **Supplemental File S4**). This was done approximately 3 weeks after completion of the project, at which point they would have received their continuous assessment marks, but this was prior to the end-of-semester exam for the course. Both semi-quantitative, directed questions and open-ended questions were included in the survey. All respondents strongly agreed or agreed with the statement that "The assignment was useful, and I learned a lot form it." More specifically, they reported learning a lot about their own group's topic and somewhat less from watching the videos of other groups. The average estimate of time spent working on the assignment was 8 h, but individual estimates ranged from 4 up to 15 h.

A couple of questions asked about the system of peer input into assessment of the assignment. Respondents overwhelmingly favored the system whereby students within a group provide input into the marking for individuals in their group, with only one student expressing a preference that everyone in the group get the same mark. However, respondents seemed a bit more wary about students providing input into the marks for other group's videos with one third of respondents preferring that the lecturer decide the group mark.

Having changed the role-play to a videoed format rather than an in-class performance, it was important to get input about students' feeling on this and also assess to what extent they watched the videos outside of class. 100% of respondents expressed a preference for shooting a video rather than performing the role-play in class. The vast majority of students had watched at least one video subsequent to them being shown in class, and half had shown them to others outside of the class. Another way to assess students use of the videos is through YouTube's analytics features. The five videos that were hosted on the instructor's YouTube channel were not searchable and so most views of the videos are likely to come from students on the course who were given the link to the videos. **Figure 3B** shows the viewing data for these five videos from the time of completion of the assignment until the end of the semester. Interestingly there is a distinct peak in viewing time for all the videos just before the final exam. This is a strong indication that students are using the videos as revision aids, an observation that is backed up by informal conversations with a small number of students.

The survey also posed two open-ended questions, one asking about any other (i.e., non-academic) benefits of doing the videoed role-play assignment and the other asking for further comments, feedback or suggestions? Apart from some concerns that not enough time was given to complete the assignment the comments were overwhelmingly positive. A selection of comments (edited for brevity) that represent the main points made are shown below:

- "I found it extremely beneficial in making friends with people in our suddenly small course group……. It also helped me reach out to exchange students. Furthermore, it is the first project we have been assigned that entails teamwork and initiative skills and as a result, I was able to identify my weaknesses and strengths within a team."
- "It was a really fun way to learn about our topic and I will definitely remember our topic a lot better now than I would had I just studied it on my own."
- "It made learning extremely fun and unforgettable. I would love if other modules had a similar aspect to the coursework. The best thing about the group assignment was that it was

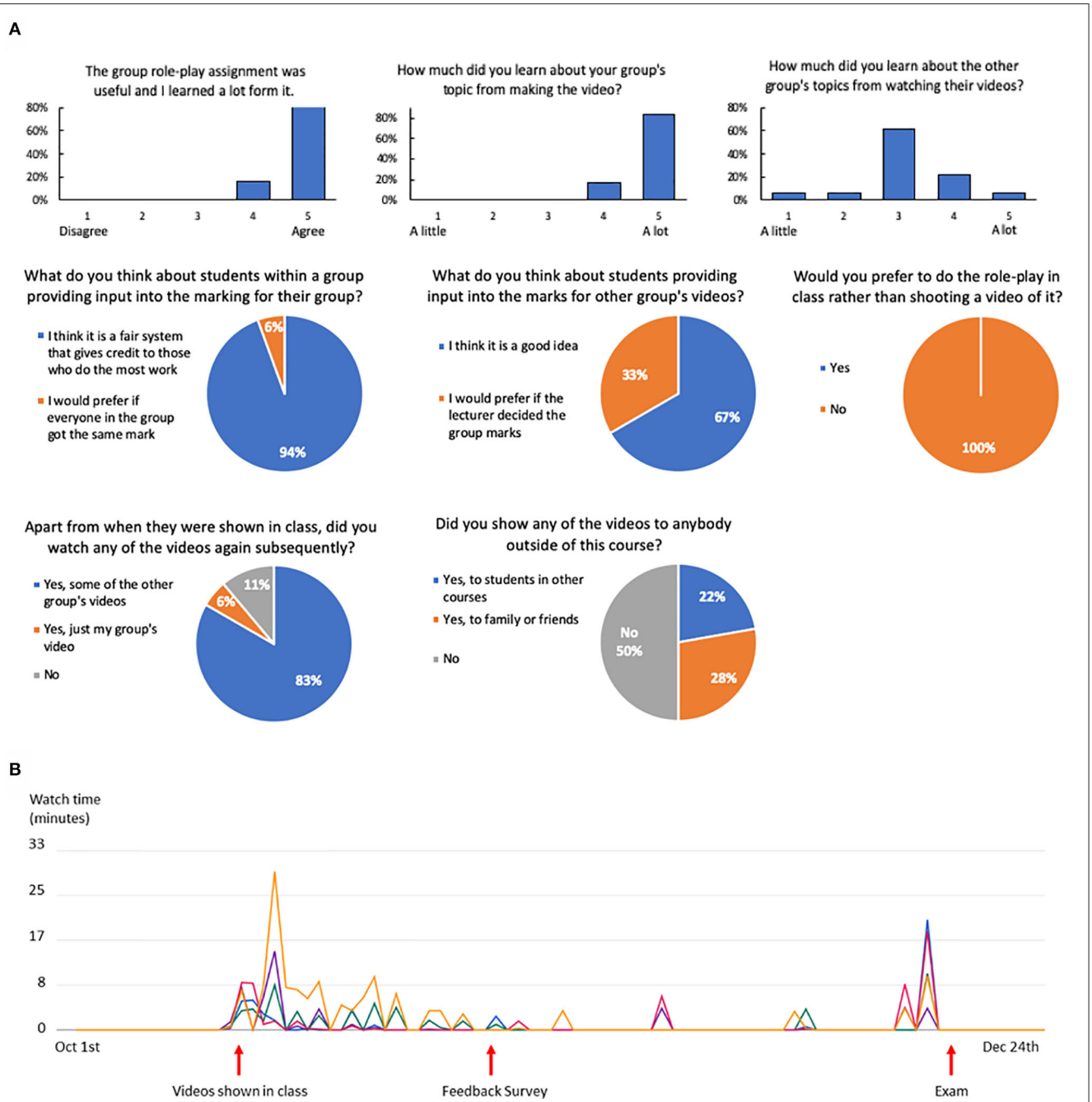

FIGURE 3 | Student feedback survey results and watch time data from YouTube for five role-play videos. **(A)** Results of an online student feedback survey conducted using Google Forms 3 weeks after completion of the role-play project. Eighteen responses to the survey were obtained, which represents a response rate of approximately 40%. The full survey questionnaire is provided as **Supplemental Data**. **(B)** Watch time data for five of the role-play videos (each color-coded differently) was obtained using YouTube analytics. The timing of the end of the assignment when the videos were first shown in class is indicated, as well as the timing of the feedback survey and the end-of-semester exam for the course. Average video length is about 4 min. The peaks in watch time immediately preceding the exam thus represent several of the videos being viewed multiple times and is indicative of their use as a revision aid.

pushing us to be creative and have fun with our ideas which was a welcome change from the usual more 'serious' college work, and in this way I think we all learned a lot more than we would have done if we didn't have this group assignment. I was really happy with it....."

- "I really enjoyed the assignment. I thought it was an excellent tool in learning..... Exercises like this should be the norm in our course."
- "Though there was a lot of work, planning and preparation involved in the making of our video, I thoroughly enjoyed it.

It was very informative to our groups (and hopefully the other groups) as well as being very enjoyable and a great laugh which I feel comes across in the video along with the effort put into the research of the topic."

- "As an international student, it helped me to meet other people in the class, which made me feel more welcome. I also then had someone to talk to and ask questions to when finals came around and I was adjusting to a different testing system."

Instructor Perspectives

This role-play had been running quite successfully for 4 years with the groups performing the role-plays in front of the class. While this worked well and was popular with the students, there were a number of draw backs. Firstly, it generally took two 1-h classes to accommodate the six performances as each group took time to get organized and set up for their role-play. Also, those who had not yet performed their role-play were probably thinking about their own play and not fully paying attention to the other performances. In addition, the groups who presented first felt at a disadvantage as groups performing on the second day could get ideas from their plays. Finally, once the play was performed, there was no lasting record of it and many learning opportunities were thus lost.

These issues prompted the decision to move to videoed-role plays in the 2018–2019 academic year. Submission of all videos at the same time was fairer and meant that when the videos were shown in class students could relax and focus on the other group's videos without distraction. In addition, because the videos were typically 4–5 min in length, they could all be shown in a 1-h class and crucially could be viewed over again. The evidence from the feedback survey and YouTube analytics view time data indicates that a significant proportion of the class did re-watch the videos and also used them as revision aids before the end-of-semester exam. Other advantages of videoing the role-plays include: (1) that it allows students to document the hard work that they have put into the assignment, potentially incorporating it into a digital portfolio of their work and even on their resumes (2) that the instructor can document the approach in the context of the scholarship of teaching and learning and can share the approach with colleagues in professional contexts; (3) that a broader variety of role-plays including animations and narrated sketching can be accommodated; (4) that students can share their work with family and friends; (5) that the instructor can re-watch the videos to more accurately assign grades and correct any errors/misconceptions; (6) that students get to incorporate diverse extracurricular skills, talents and interests into their coursework.

An initial worry with adopting the videoing of the role-plays was that the groups would not have the technical ability to produce a good quality video essentially without any instruction or guidance. This concern was clearly unfounded as all groups exceeded what was expected in this regard, with many including opening and closing credits, using extensive video editing, sound tracks, voice-over, variation of frame rate, special effects and even adding a "bloopers reel" at the end of the video. Presumably, with group sizes of 7–8 students at least one member of the group had the technical know-how required or the initiative to seek it out. A couple of potential downsides to the videoing approach can be imagined however. Probably the most significant is that it imposes an extra workload on students, with some students reporting 15 h spent on the project across a 2-week period. Nevertheless, only a couple of complaints about the workload were voiced and were more related to the timing of the assignment in relation to other coursework. This is something that can be addressed going forward. Another potential issue is that the use of student-produced videos as revision aids will be counterproductive if they contain errors or scientific inaccuracies. I did not identify major inaccuracies in the role-plays but it is certainly true that the short videos don't capture every aspect of the assigned topic and may omit some significant details. Importantly, all topics are also covered in detail in regular lectures. Still, if errors or inaccuracies are noted in the videos they must be corrected. This is something that can be addressed when discussing the videos in class or by posting a correction in the form of a comment associated with the video on YouTube. Some comments of this type were posted by the instructor to point out minor misconceptions or details that were omitted in some of the videos.

DISCUSSION

The approach described here is novel compared to existing reports in the literature on the use of role-plays in science education in a number of ways. Firstly, the subject matter (cell biology) and the education level (advanced undergraduate courses) are not well represented in the existing role-play literature. Secondly, the role-play templates described here are not prescriptive beyond specifying the topic and the cast of "characters" to be played. This format encourages student creativity and ownership of the role-play, should make it easy to apply to other topics in diverse subject areas and is very "hands-off" from the instructor perspective. Thirdly, an original system for peer input into assessment is presented. Finally, the use of student-produced video as a way to document role-plays on core science topics is not widely reported. Videoing of the assignment has several practical and pedagogical advantages, expanding the ways in which the students can explore the topic and the range of talents and creative thinking that they can bring to bear on the task, for example by using animation or narrated drawing.

The potential for analogies in the context of drama such as role-playing to help learners to rationalize between their world of knowing and the science world of knowing has been highlighted (Braund, 2015). One result of giving students a large degree of freedom was the development of very novel analogies to explain their assigned cell biological process in some cases (**Table 3**). Analogies can help science students to conceptualize abstract ideas and things that are either microscopic or too massive to observe directly and are an invaluable tool frequently employed in teaching (Aubusson et al., 2006). Analogies link newly acquired concepts to previously known ones (Kiliç and Topsakal, 2011). To be most effective then, analogies must be made to concepts that students already know and can relate to. It is likely that the student, rather than the teacher, is best placed to identify such already-known concepts. There is much to be

said then, for allowing students to develop their own analogies and to share them with their peers rather than having teachers develop analogies that the students may not be able to relate to. Indeed, there is some evidence that student-centered analogies lead to increased conceptual understanding compared to teacher-centered ones (Kiliç and Topsakal, 2011). Videoed role-plays of the type described here can thus be a source of novel and student-relevant analogies that might be used by instructors to enhance student learning of difficult concepts in subsequent years.

The system used here to obtain peer-input into assessment is very simple, just asking students to cast votes to rate other student's contribution to the project. Students are not asked to justify their voting. Neither is there extensive documentation of the contribution that each student made to the project—something that probably runs against best practice with assessment of group work. However, this assignment is worth a relatively small proportion of the overall marks for this course and thus a simple system that is not overly complicated is needed. Student feedback strongly supports the use of peer-input in assigning marks to individuals within groups. The assessment system used here thus provides some recognition of individual student effort, though it would certainly not be robust enough for larger assignments or whole courses based on group work. Notably, the feedback survey data suggested that there was more apprehension about the same system being used to provide peer-input into the grading of each group's roleplay by the rest of the class. Observing these "between-group" voting patterns, it was apparent that students were probably placing more weight on the "*entertainment value*" vs. the level of scientific detail of the role-plays. The student input for other group's videos was thus heavily moderated by the instructor to reward both of these aspects. Going forward peer-input will probably be restricted to "within-group" assessment, with the instructor deciding the group marks without student input.

An acknowledged limitation of this report is that small class size and lack of control groups preclude an objective and quantitative analysis of the impact of the assignment on student learning of the assigned topics compared to traditional or other active learning approaches. Notably, all assigned topics were also covered in detail in lectures and, perhaps because of this, improved exam performance was not noted for students in a particular group on questions that related directly to the topic of their role-play (data not shown). Thus, while the reported time spent on the assignment (8 h on average) and the videos themselves strongly indicate that students have engaged with their topics in an in-depth manner, this was not reflected in better performance relative to the rest of the class in the end of module assessment (consisting of essay-style and multiple choice questions). One might argue that access of all groups to each other's videos may have spread the benefit of each role-play across the whole class. However, it is also entirely possible that the role-play does not enhance student learning of the course material, or at least not in a way that is measurable in the examination format employed.

Even if this is the case, I believe that the assignment is still hugely beneficial to students and that the real value of the exercise lies in facilitating students to:

1) Engage with members of their class including international students that they otherwise would not know (generating a sense of camaraderie within the class)
2) Discuss a scientific topic in depth with each other (something that many will not do spontaneously) and thereby gain confidence for future literature and research projects
3) Engage in a team exercise, recognizing and developing their teamwork skills
4) Bring their non-scientific talents and skills to bear on a scientific assignment
5) Produce an output (the video) that can form part of a learning portfolio.

It is likely therefore that this role-play exercise achieves several of the benefits of active learning proposed by Shimazoe and Aldrich (2010), such as teaching social skills & civic values, teaching higher order thinking skills, promoting personal growth and developing positive attitudes toward autonomous learning. These benefits are not easily quantified but nevertheless contribute to interpersonal skills and other desirable graduate attributes that are unrelated to discipline-specific knowledge. Indeed, a survey of alumni several years after graduation found that skills and experiences that they had developed during role-play exercises in an analytical chemistry course had served them well both professionally and personally, reflecting a "wealth of non-achievement-based outcomes associated with cooperative learning" (Jackson and Walters, 2000).

Overall, I propose that the videoed role-play assignment format described here can be readily introduced as a form of collaborative learning into undergraduate cell biology and biochemistry courses and beyond. The instructor workload relates mainly to assessment, as the group work itself is completed outside of regular class hours with minimal instructor input. Once students were reassured that they would get equitable reward for their effort, there was little evidence of the frequently-reported resistance to the group work activity (Shimazoe and Aldrich, 2010). In fact, comments in open-ended questions from students who responded to the feedback survey indicated that they overwhelmingly enjoyed the group work activity and would like to see more such assignments as part of their courses. These observations support the case for role-plays as a learning paradigm in undergraduate science education and suggest one model by which this can be achieved.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study and for publication of any identifiable information was provided by the participants.

AUTHOR CONTRIBUTIONS

PY conducted the study, analyzed the results, and wrote the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2020.00115/full#supplementary-material

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