Biochemistry Without Borders: A Case Study Utilising Infographics

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Abstract:

This paper addresses a case study on the implementation of an online learning exercise utilising infographics in undergraduate Biochemistry and General Chemistry courses at the University of Roehampton (UoR) and Hostos Community College (HCC) of the City University of New York (CUNY). Students at UoR were asked to create infographics on topics related to the four major classes of biomolecules: carbohydrates, lipids, proteins and nucleic acids and these infographics were shared with HCC students in an active learning exercise which incorporated peer evaluation and feedback. We highlight the various teaching and learning strategies, as well as the challenges related to the implementation of digital tools, in the educational process during the COVID-19 pandemic to maintain student engagement and active learning. Student feedback revealed positive learning gains on biochemistry concepts related to the four biomolecules. The exercise was viewed favourably by students, with learners indicating the acquisition of digital skills to effectively represent and visualise their understanding of biochemical concepts and explain these processes to peers.

Keywords: Undergraduate, Biochemistry, General Chemistry, Communication, Infographics, Internet and Web-based learning

▪ Introduction

The COVID-19 pandemic forced higher education institutions to pivot to online teaching early in 2020 to accommodate emergency measures based on social distancing. Science courses were among many of the courses affected and their remote delivery required unique and non-traditional pedagogical strategies to maintain the level of student engagement and participation without affecting grade outcomes.

This would prove particularly challenging at the University of Roehampton (UoR), in the first year undergraduate Chemistry of Life module, where students access this module from four programmes: Biomedical Science, Biological Sciences, Zoology and Nutrition and Health [1]. The General Chemistry I course at Hostos Community College (HCC) of the City University of New York (CUNY), is offered to undergraduate students pursuing careers in science and engineering [2]. The science courses at HCC, including General Chemistry I have also experienced the challenges related to a sudden transition to an online modality.

Considering the unprecedented impact of the pandemic on the academic year, we decided to implement an active learning exercise to support the diverse student body, in both institutions, where the students could participate in an online learning project that would encourage and incentivise engagement and participation in scientific communication and learning. Such an exercise would encourage UoR students to explain complex subject matter, like biochemistry concepts by successfully internalising the material and then teaching it to HCC students, who would learn this new material not covered in their course. This activity allowed the HCC students an opportunity to relate the chemistry concepts, that they had been learning in the General Chemistry I course, to their application on an example of the structure and function of the four biomolecules from the infographics from the UoR students.

For this active learning exercise, we utilised the material covered at UoR on the four major biomolecules: carbohydrates, lipids, proteins, and nucleic acids. Learning about these topics would benefit from the use of visual aids to reinforce understanding of the relationship that exists with the molecular structure and function of each biomolecule. It has been shown that complex concepts are comprehended more efficiently and effectively by using both text and visual aids when compared with just text [3,4]. The means by which to encourage visual active learning was inspired by the website Compound Interest, produced by Andy Brunning, which stores chemistry-

focused infographics about products and items encountered in everyday life as well as infographics on SARS-CoV-2 and RNA viruses, the COVID-19 pandemic, vaccines, testing and the importance of handwashing [5,6]. Infographics can aid in presenting complex content in a way that supports cognitive processing as well as making it more permanent in our minds [7–9]. Infographics are often used to engage and inform the public on complex issues [10] such as public health [14,15], medicine [16–18], climate change [19] and in developing educational material to combat misinformation for example, in the case of the SARS-CoV-2 virus and the COVID-19 pandemic [20]. Most importantly, previous research has shown that infographics have been deployed successfully within chemistry as a teaching tool to help students become competent in information literacy, visualisation of biochemical concepts and aid in communication skills at the undergraduate level [10–13].

According to the Feynman technique [5], students engage in active learning in cycles of teaching a concept that they want to learn about, identifying and reflecting on any gaps in their explanation and simplifying their explanation to teach it again.

Thus, implementing an infographic exercise via remote learning offered up an opportunity to incentivise greater engagement that is tied to the following learning outcomes:

(i) students would engage with the course material while learning about real-world examples of the four biomolecules and reviewing their peers' infographics and

(ii) students would gain valuable experience learning digital tools to communicate scientific concepts to their peers and a broader audience on a virtual platform.

This is supported by recent research that shows students in a wide range of chemistry courses and at different levels [11–13,21–28], often benefit from student-generated instructional material [29,30] like infographics more than instructor-generated ones.

▪ Methods

UoR students were taught the fundamental concepts related to the four biomolecules: carbohydrates, lipids, proteins, and nucleic acids, utilising content from both printed [31] and online [32] resources (**Figure 1**).

The optional weekly infographic assignment was then introduced to the students to:

(1) incentivise weekly revision of the pre-recorded material and the live session.
(2) participate in peer review with other UoR and HCC students, to eventually use the feedback from these sessions to revise the infographics to answer an optional question on the final exam.
(3) obtain a participation certificate for remote discussions with HCC students.

The students were assigned a particular topic from a list for each biomolecule (**Table 1**) to maintain the scientific narrative, but they were also encouraged to choose a topic aligned to their registered programme: Biomedical Science, Biological Sciences, Zoology or Nutrition and Health, to allow for individualisation and personal interest.

Each student was asked to create four infographics, one for each of the four biomolecules, that was visually appealing, quick to read and easy to understand. Examples of infographics from Compound Interest [5,6] were provided for content and style ideas but the students were encouraged to use other online resources to find examples. They were given online resources on how to create effective infographics, and links to the University guides on how to search the literature for content and images, and how to effectively reference these sources to avoid plagiarism. To develop higher-order thinking skills, the students were asked to independently evaluate the literature, synthesise the material and make their conclusions about what content is needed to generate their infographics [37].

BioRender was introduced as an online scientific illustration tool with pre-set professional icons and templates [33] along with tutorials from the BioRender YouTube channel [34]. Students were encouraged to take advantage of other existing graphic design tools such as Canva [35], Piktochart [36] and PowerPoint, with images and content referenced appropriately. The students were made aware that BioRender and Piktochart have a free pricing plan with a five graphic limit, so if they registered for the free account it would still be suitable since the assignment required creating a maximum of four infographics.

Most students utilised BioRender since they could choose from a variety of images, templates, and formatting tools to make their infographics (**Figure 1**). Since the majority used the free version of the BioRender tool, the icons were already available within the tool and did not need to be separately referenced, as the infographics had an embedded BioRender watermark, alerting the reader to what was used to create it. Most students chose the default setting for the canvas size, 10Wx7H

and could then export the completed infographics in the .PNG format at the 72 DPI resolution, which is the only available resolution for the free version. The .PNG images could then be embedded into a text editor for submission to Turnitin.

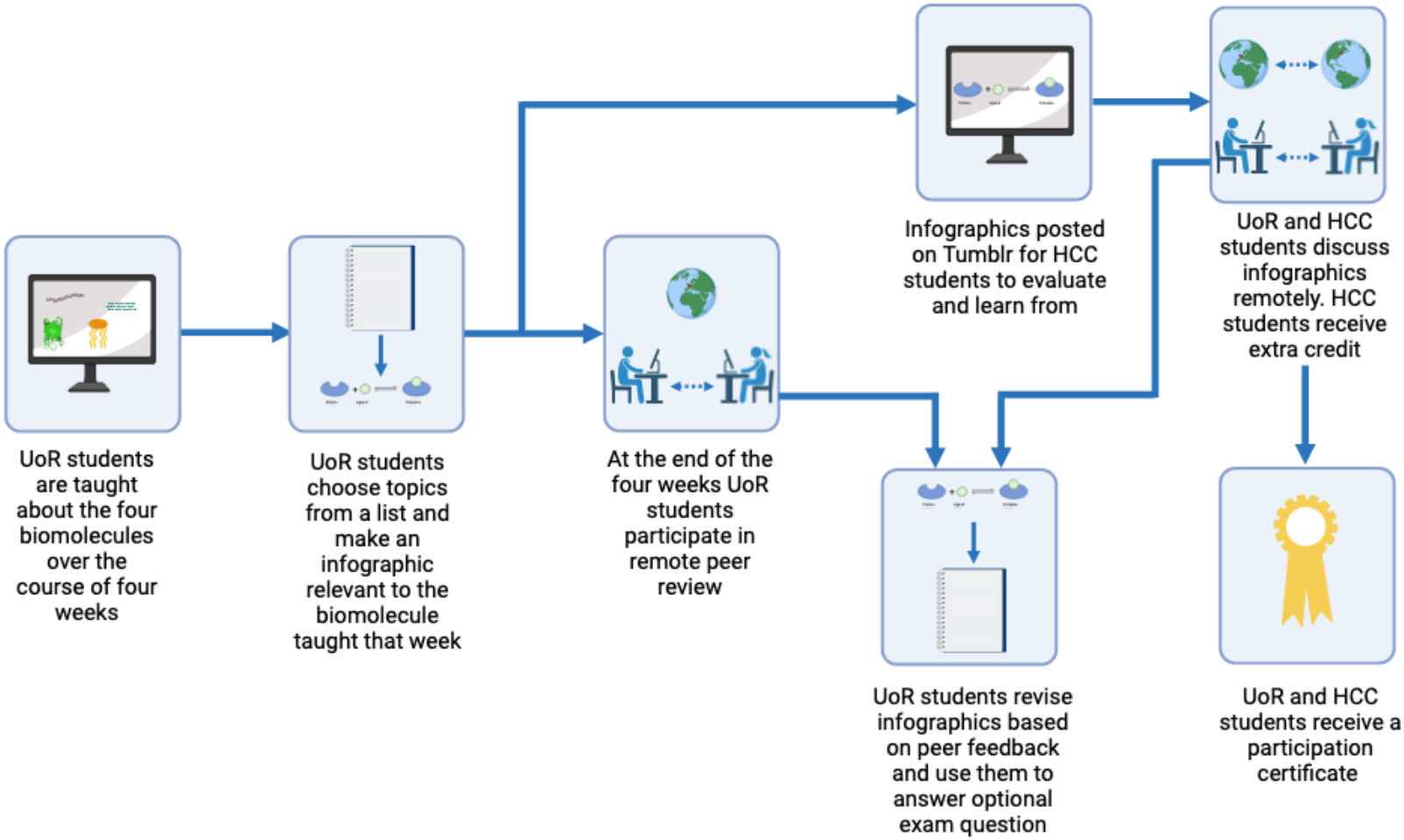

Figure 1: Outline of the infographic exercise. Image created with BioRender [34].

After submission of their infographics to Turnitin [38] via the module Moodle site [39], UoR students were able to peer review two randomly assigned infographics, with instructions provided by the UoR Library services [40] (**Figure 1**). The Zoom videoconferencing platform [41] facilitated remote live instructional sessions to address any technical issues and to allow students to discuss the task with each other in breakout rooms. As a contingency to possible technical issues preventing Turnitin peer review, the submitted infographics were also uploaded to Tumblr [42,43], archived by group and biomolecule topic. A rubric grading guide was supplied to the students, which consisted of nine questions to aid in their peer review evaluation. The rubric is included in the **Supplementary Material**.

Tumblr also facilitated the online sharing of these infographics to the General Chemistry I students at HCC (**Figure 1**). HCC students could familiarize themselves with the biochemical concepts not covered in their General Chemistry I course and learn about the application of some concepts of general chemistry on an example of the structure and function of the four biomolecules. HCC students were tasked with peer reviewing infographics on each of the four topics uploaded to Tumblr [42,43] and were awarded extra credit, that contributed to their final grade for the course.

Both HCC and UoR students also participated in a remote discussion session, where UoR students could explain their infographics and address possible questions from HCC students (**Figure 1**).

UoR students could further use the feedback from this session and the UoR peer-review to revise their infographic and use it in the final exam to answer the following optional 200 word question: There are five unifying themes of biochemistry: Structure and Function, Information, Unity and Diversity, Energy and Matter and Interactions. Using one of these themes, discuss how it relates to the four biomolecules: carbohydrates, lipids, nucleic acids and proteins. You can use a minimum of 2 infographics to support your answer. Instructor evaluation of the infographics used in the exam and the corresponding 200 words on the above question followed the grade assessment criteria for the University of Roehampton, M Level, see **Supplementary Material**.

Students from both institutions received participation certificates; UoR students for completing the infographic task, peer-review and the discussion session with HCC students, and HCC students for peer-review and the discussion session with UoR students.

	Carbohydrate	**Lipid**	**Protein**	**Nucleic Acid**
Group A	What are carbohydrates?	Cholesterol	Amino acid mutations causing inheritable diseases	Difference between DNA and RNA
Group B	Structure and function of carbohydrates	Fats vs oils	Amino acids and primary structure	DNA and the brain
Group C	Simple vs. complex carbohydrates	Fatty acids and Triglycerides	Antibodies	DNA sequencing
Group D	Carbohydrate benefits	Lipid benefits	Bioinformatics	DNA vaccines
Group E	Carbohydrate deficiency	Lipid metabolism	Chaperone proteins	DNA-protein interactions
Group F	Good carbs vs Bad carbs	Lipid receptors and transporters	Denaturation and protein folding	DNA, Genes and Chromosomes
Group G	Sources of carbohydrates: Fruits and vegetables	Lipids in disease	Enzymes	Double stranded RNA
Group H	Sugars and Starches	Lipoproteins	Infectious Proteins	Mitochondrial DNA and disease
Group I	Cellulose	Membrane lipids	Protein deficiency	Mutations and disease
Group J	Fibers	Monolayers vs Bilayers	Protein Misfolding and degenerative diseases	Nucleic Acid Structure and Function
Group K	Corn syrup	Omega-3 Fatty acids	Protein structure and function	Protein synthesis
Group L	Why is sugar bad?	Phospholipids and glycolipids	Protein structure prediction	RNA origami
Group M	Sugar highs and fat storage	Saturated vs Unsaturated fats	Protein-protein interactions	RNA vaccines
Group N	Diabetes	Soaps	Protein-small molecule interactions	RNA viruses
Group O	Insulin	Sources of fats	Quaternary structure	RNA-binding proteins in genetic disease
Group P	Glucagon	Steroids	Secondary structure	RNA's role in cancer
Group Q	Artificial sweeteners and other sugar substitutes	Structure and function of lipids	Sources of proteins	Storing digital data in DNA
Group R	Are carbohydrates more filling than protein?	The good and the bad about fats	Tertiary structure	Synthetic DNA
Group S	Do carbohydrates make you fat?	Waxes	Types of proteins	Types of RNA
Group T	Carbohydrate-based therapeutics	What are lipids?	What are proteins?	What are nucleic acids?

Table 1: List of suggested infographic topics listed by biomolecule topic and group, to aid in archiving.

- **Findings**

57 of the enrolled 200 students in the UoR Chemistry of Life module, in the 2020-2021 academic year, produced the carbohydrates infographic, the first biomolecule introduced in the lecture sessions. Over the weeks the number of students who participated gradually decreased to 37, 23 and 20 for the lipids, proteins, and nucleic acids infographics, respectfully. From the infographics that were submitted, it was clear that some students were able to produce high-quality and attractive infographics, that were also suitable for a broader audience. They were able to synthesise sometimes complex concepts and utilise some imaginative and creative ways in laying out the design for their infographics. The lesser quality infographics were presented more like posters or individual images without a narrative. Some examples of infographics are included in Figure 2. You can also see all infographic submissions on Tumblr [42,43].

At the end of the term, the Chemistry of Life module feedback allowed for free-text comments (See **Supplementary Material**). The 20 UoR students who participated in the discussion session with the HCC students, expressed satisfaction in completing the assignment. Students particularly enjoyed the interactivity with peers and learning new digital literacy skills, which allowed them to learn from each other, among other benefits [44]. One of the questions asked was “What did you like most about Infographic exercise?” Some comments included “It introduced me to BioRender and showed me an enjoyable method of revising by making infographics”, “Nice to hear from different students and learning new skills in terms of infographics”, “Being able to interact with other students with the same interests” and “The flexibility of giving my point of view”.

At the end only 20 UoR students participated in this exercise. The students who chose not to participate at the beginning or stopped contributing weekly commented that “although the task was interesting, I did not see the benefit in doing something that was optional” and “I did not have the time as I had so many other things going on in my other modules”. We believe, that if this exercise was introduced to students as a mandatory component of the course we could expect a higher participation level.

Those that did complete the assignment were asked if there was anything they did not like about the assignment. Some comments included “Because it was online there were connection problems”, “Not being able to see people properly as most

people didn't use their cameras" and "Would have liked to have talked more to the other people(they didn't talk much) maybe have something to work on in the breakout room organised to work on together? even a tiny quiz to get them to also talk".

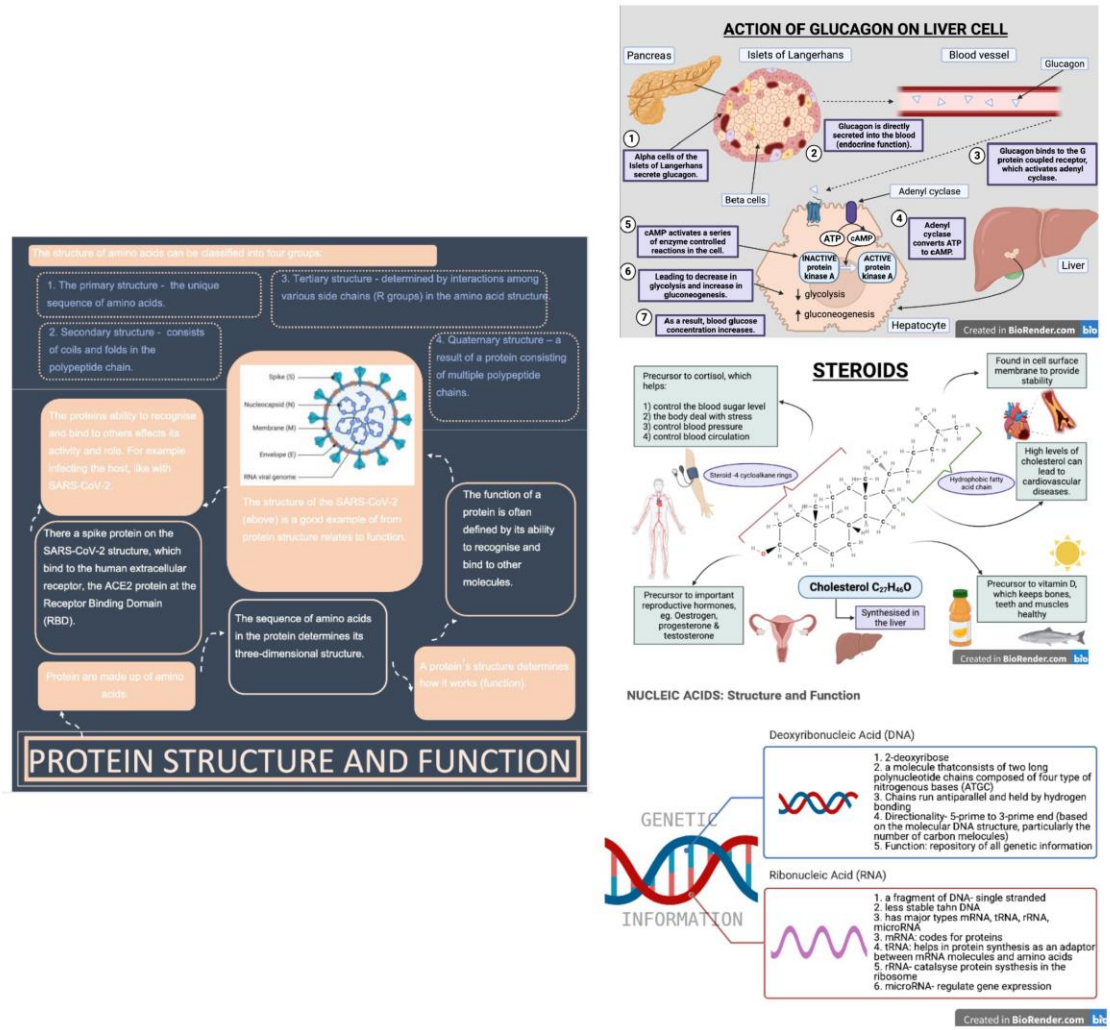

Figure 2: Examples of student-produced infographics.

Evidence from the submitted infographics shows that most students achieved the learning outcomes for the task. Students were able to successfully research the literature for their infographics and connect the course material to real-world examples of the four biomolecules. They were then able to participate in the peer review process both with other UoR students and with HCC students. In addition, students acquired valuable experience learning digital tools to communicate scientific concepts to their peers and a broader audience on a virtual platform.

Students also emphasised that the assignment allowed them the flexibility to independently complete the task with a minimal amount of staff direction. Most students completed the infographics by the weekly deadline, with only a few days of grace needed.

At UoR, the grades awarded for the infographics show overwhelmingly that the students did well, with 85% scoring in the top-grade category (**Figure 3**). Other positives include the social side of the activity. Students expressed how they felt less isolated with the distance learning aspects of the module and looked forward to the remote discussions as a chance to ask each other questions as well as speak with the HCC students.

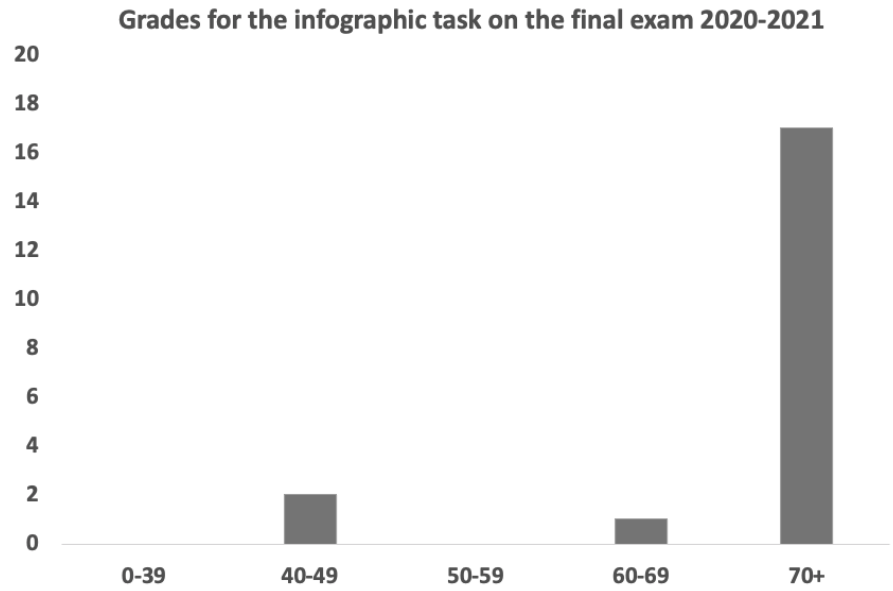

Figure 3. Infographic assignment grades for the Chemistry of Life module, 2020-2021.

- **Contributions to the field**

Infographics were introduced as a useful pedagogical tool to teach the four major classes of biomolecules, which form the basis of biochemistry. Infographics facilitated the learner's comprehension of the relationship that exists with the molecular structure and function of each biomolecule. This case study adds to the existing evidence that infographics are effective in educational contexts because they can be used to capture the learners attention and visualisation of complex biochemical concepts, enhance retention and aid in science-communication [10–13]. This infographic exercise also helped the learners with acquiring technical literacy skills and allowed them to learn how to organise information in a logical way and find trustworthy literature sources.

Although the infographic learning exercise was designed for Biochemistry and General Chemistry undergraduate courses, with specific topics (**Table 1**), it could easily be adapted to other Science, Technology, Engineering and Mathematics (STEM) courses and learning levels.

▪ Conclusions

The infographic assignment was introduced to improve student engagement and retention of the learned material. This case study revealed that online instruction must be strongly incentivised or made a required assessed course component, to improve student engagement. This active learning exercise is an example of a pedagogical tool that facilitated comprehension of complex scientific material, enabled students to learn and teach each other and introduced new digital skills. Students who participated were more invested and found that they shared common goals which could be exploited in developing good study habits and social skills. We intend to continue exploring the potential of this active learning exercise with collaborative projects between both institutions.

Summary Points

- Infographics provide students with the means to revise weekly biochemistry material.

- The task allows students to connect to the course material while learning about real-world examples of the four major biomolecules: carbohydrates, lipids, proteins, and nucleic acids.
- The task is flexible and can be done independently without instructor intervention.
- Students gain valuable digital skills in making the infographics and participating in the remote peer review exercise.
- Students interact remotely with peers at UoR and at HCC to discuss, learn and explain biochemical concepts.

Author Contributions

MAS and AI conceptualized the case study and prepared the manuscript. All authors critically reviewed and edited the content and approved the final version.

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Notes

According to the guidelines from the University of Roehampton (UoR) Research Integrity & Ethics Committee, the results from this case study activity falls under the umbrella of 'quality assurance/quality improvement' activities and did not require institutional ethics review. No student data from Hostos Community College (HCC) of the City University of New York (CUNY) was included in this case study.

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