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Research Letter

RESEARCH LETTER – Professional Development

Analysis of university student responses to the pandemic in a formal microbiology assessment

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One sentence summary: The microbiology examination assignment at Istanbul Technical University during the coronavirus pandemic is an excellent example of assessing wider scientific literacy with respect to application in society.

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ABSTRACT

During the coronavirus pandemic, second-year students on the B.Sc. molecular biology and genetics degree at Istanbul Technical University sat an open-ended online exam for a microbiology course in which one of the compulsory questions asked how the course had helped them during the first phase of the pandemic (April–July 2020). Fifty of 69 students gave consent for their (anonymous) responses to be analysed in order to discern any key ways in which their knowledge had been applied. The aim of the study was to investigate whether taking an advanced microbiology course increases understanding of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) pandemic and has a positive impact on student behaviours with respect to public health practices. Findings were divided into four major themes: course content (information), application of course content to behavioural change (practice), professionalism and their 'audience' whilst at home in lockdown (family and friends). Social distancing, wearing face masks, and hand and surface hygiene were described as important behaviours, with this practice informed by their basic microbiology knowledge. This paper describes a scenario where rote assessment can be used to assess wider scientific literacy with respect to application in society, providing students with an opportunity to incorporate and apply their learning into real-life situations, whilst tutors can assess constructivist learning, conceptual understanding and impact on student behaviour.

Keywords: microbiology education; scientific literacy; coronavirus lockdown; qualitative evaluation; analysis of text; COVID-19

INTRODUCTION

Higher/university education, like almost all levels of education, often follows a unidirectional path of learning followed by assessment. Over recent years, academics have been adjusting assessments away from the closed-book exam format, which is widely noted for not aligning to the constructivist educational approach—acknowledging that students build their

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understanding of science—that is widely considered a fundamental pedagogic theory (Driver *et al.* 1994; Williams and Wong 2009). However, despite academic preference to expand assessment types, examination of rote learning is often preferred by students, and may also be utilized to assess understanding, translation/application of information, and extension of knowledge and experience (Quitadamo and Kurtz 2007; Watters and Watters 2007; Gikandi, Morrow and Davis 2011).

In the microbiological sciences, a report by the American Society for Microbiology has called for academic assessment to focus on conceptual understanding (Merkel 2016). This has been echoed with a call for greater science literacy—with acknowledgement that other impactful disciplines (e.g. finance) are better understood than those potential impacts relating to microorganisms (Timmis *et al.* 2019). Over recent years, more focus has been placed on such conceptual understanding, ranging from the formal teaching environment to educating the public about important societal impacts relating to microorganisms—for example antimicrobial resistance (AMR) (Redfern *et al.* 2020).

In early 2020, it became clear that what would become the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) pandemic would impact course delivery and assessment of learning, providing significant challenges to educators and university students across the globe, because many practical courses were stopped, and theory was delivered in online environments (Brancaccio-Taras *et al.* 2021). During this time, scientific literacy relating to microbiology became a highly desirable attribute, a requirement for understanding government policy and public health intervention and facilitating critical evaluation of media reports. Thus, the impact of SARS-CoV-2 allowed university students currently studying microbiology and molecular biology to apply, understand and evolve their learning in a global emergency situation—and, in comparison to the lay public, the students became experts.

This paper describes how one university, through a written (online) examination question, used the coronavirus pandemic as a focus for application of microbiology theory into behavioural change and science communication. The aim of this study is to determine, through self-reporting, whether taking an advanced microbiology course increases understanding of the SARS-CoV-2 pandemic and has a positive impact on student behaviours with respect to public health practices.

As one student wrote 'after the pandemic, we as the world started to live in a live microbiology lesson' [*sic*]—acknowledging the increased scientific literacy the public will have with regard to microbiology.

METHODS

Setting and sitting the examination

In Istanbul Technical University (ITU), undergraduate students enrolled on the molecular biology and genetics B.Sc. programme study two concurrent compulsory courses in microbiology in their sophomore (second) year, during the spring term. One of these courses is theoretical and the other is practical, and both are instructed in English (Table 1). In the academic year 2019–20, both courses started at the beginning of the spring term (week of 10 February 2020). However, due to the coronavirus pandemic, all in-person sessions were cancelled from 16 March 2020. The students were sent home, and online lectures began on 6 April 2020, lasting until the end of the spring term (9 June 2020). Regarding the Microbiology Laboratory course, the initial introduction session and the first two experiments on sterilization techniques, preparation of culture media, methods for pure culture isolation (spreading/streaking plates) and the bacterial growth curve took place in person during the first 5 weeks of the academic term, but the remaining four experiments took place via online/video lecturing. The students had had no formal teaching regarding coronavirus. They were encouraged, during the first online lecture on 6 April 2020, to join the free Coursera course on epidemics and COVID-19 (by Johns Hopkins University) (Coursera 2020).

The final exam for the theoretical course consisted of two parts. Part 1 was a take-home exam where the students had 6 days to answer three open-ended questions about microbiology topics covered in the first half of the academic term. Part 2 was an open-book exam where the students had 2.5 h to answer five questions that aimed to measure their knowledge on the topics covered in the second half of the academic term. Both assessments were submitted online to the course instructors. A compulsory question from the open-ended take-home exam questions challenged the students to explain how their learning of fundamental microbiology helped them and their families during the lockdown period. This question was designed to enable application and extension of the students' experience of microbiology. Due to the rapid nature of change, the university did not require assessments to have a marking scheme. As the course was taught in English, the exam was also written in English.

The question was 'Please explain in detail how the microbiology information you gained in our lectures about infectious diseases and their epidemiology, aseptic techniques of microbiology (sterilisation, disinfection, antimicrobial techniques and agents) helped you during the COVID-19 pandemic. Please give detailed examples of how you used your microbiology and/or scientific knowledge in helping/informing people in your family and/or your community and/or how different was your behaviour and attitudes than the others (non-microbiology/molecular biology people) around you during the COVID-19 pandemics and the lockdown period.' The instructor anticipated answers would mention scientifically accurate information in addition to personal experience.

Analysis of student responses

Data (student responses) were collected as part of a formal examination at the ITU—and as such, collection of data was not for the primary purpose of this analysis. Therefore, use of data followed advice regarding secondary use of data provided by the British Educational Research Association Ethical Guidelines for Educational Research (BERA 2018), which included anonymizing data and seeking consent for inclusion in the study following the completion of the examination. It was explained to students that their responses could be used as part of a research project and students were asked to provide informed consent in writing if they allowed their response to be included in the study. Of the 69 students who answered the exam question, 50 provided informed consent to being part of this study.

In order to identify whether there were any key themes in the student responses, a qualitative approach was taken for the analysis (Cohen, Manion and Morrison 2017; Verran *et al.* 2019). The essays were combined into one document containing 27 833 words (with an average of 556.6 words per response) and three academics (the authors/assessors) read the essays and independently identified themes that emerged. The separate analyses were compared so that any differences in staff perception might be identified, and that no important themes might be

Table 1. Description of the two compulsory courses BIO216E Microbiology and BIO216EL Microbiology Laboratory.

	BIO216E Microbiology	BIO216EL Microbiology Laboratory
Delivery mode	Theory	Practical
Content	Three hours of lecture delivery a week, over 14 weeks	Laboratory classes were delivered every 2 weeks, covering six experiments and an introduction session (aseptic technique, report writing, etc.)
Topics	• Introduction to microbiology • Scope and history of microbiology • Microscopy and staining techniques • Sterilization and disinfection • Characteristics of prokaryotic and eukaryotic cells • Microbial growth and microbial cultures • Factors affecting microbial growth • Microbial genetics • Applications of microbial genetics • Antimicrobial therapy • Host–microorganism interactions • Applied microbiology	• Introduction to the microbiology laboratory: safety rules and guidelines, instructions for laboratory report preparation and submission • Sterilization and preparation of culture media and methods for pure culture isolation • The bacterial growth curve: the role of temperature • The effects of pH and osmotic pressure on microbial growth and quantitative determination of bacterial numbers • Staining bacteria and endospores and spore staining • Screening of *Escherichia coli* and *Bacillus subtilis* cells for antibiotic and heavy metal resistances by a paper disc–agar diffusion assay • Identification of bacteria through biochemical testing
Learning objectives	• Learn the basic concepts of microbiology such as structure and function of microorganisms, and the principles of microscopy • Understand the principles of sterilization, disinfection and microbial growth control • Learn the basics of microbial physiology and microbial growth • Gain basic information on microbial genetics • Grasp microorganism–host relationships • Learn about basic principles of applied microbiology	• Learn the basic concepts of microbiology such as structure and function of microorganisms, and the principles of microscopy in an applied fashion • Understand the principles of sterilization, disinfection and microbial growth control by experimental applications • Grasp the basics of microbial physiology and the principles of microbial growth by experimental applications • Write scientific laboratory reports in the field of microbiology

overlooked (or less important themes overemphasized). In addition, occasional standout examples of student prose (phrases) were selected to illustrate their commitment to their studies, behaviour and care for others.

This qualitative analysis of student responses was a significant task, but it is not easy to suggest a simpler approach. Objective quantitative segmentation of the frequency of word was used on occasion (using the Microsoft Word feature 'Find') when qualitative analysis indicated that there might be some value, but the more nuanced opinions, observations and comments were only discerned through subjective scrutiny.

RESULTS AND DISCUSSION

When marking this work, the course instructor (ZPÇ) was struck by the commitment of the students to implement their learning, as demonstrated through changes in behaviour, and by the sense of responsibility they presented in communicating microbiological principles to their families and friends. As with any set of student responses, there were some that specifically answered the question, and some that provided information about coronavirus without applying it. Some provided a significant amount of information on basic microbiology without application. However, in all but one response (which provided an excellent summary of the pandemic), well-written answers gave sensible recommendations about behaviour during the coronavirus pandemic.

Since the student responses focused on the same topic, the three assessors identified similar themes. Variations between the assessors derived primarily from the degree of detail extracted from the responses, and thence the number of themes identified. Author 1 (ZPÇ) produced a comprehensive breakdown of key points relevant to the question that were made by each student. She also listed many associated themes: for example, 17 different themes in response 1, an additional one in response 2 and 10 more in response 3, and so on. Author 2 (JV) manually grouped these themes into larger categories (for example themes related to face masks), and cross-referenced them with 13 wider themes proposed by author 3 (JR) and her own five behaviour-focused headings (Table 2). A final overview enabled all themes to be categorized under the following four agreed main sections: course content (information); application of course content to behavioural change (practice); professionalism; and the students' audience whilst in lockdown at home. Each of these will be addressed in more detail below. Model answers were not prepared due to time limitation (the breadth

Table 2. Three assessors read 50 student essays on coronavirus, and grouped key points into themes. Assessor 1 (ZPÇ) generated a detailed breakdown of themes. Assessor 3 (JR) identified 13 'broad themes'. Assessor 2 (JV) listed five 'focused themes'. On discussion, these three approaches could be distilled into four 'final' overarching themes. The broad, focused and final themes are listed below.

Broad themes	Focused themes	Overall (final) themes
No discussion of how microbiology education helped in the COVID-19 pandemic or how it helped inform others	Student study-specific factors	Audience
No discussion of how microbiology education helped inform others	Behavioural changes	Information/knowledge
Directly mentions discussion with family/friends about global spread of SARS-CoV-2	Behaviour in advising about coronavirus	Applying information (practice)
Directly mentions discussion with family/friends about principles of virology/SARS-CoV-2 (e.g. mutation)	Clarification of misconceptions	Professionalism
Directly mentions discussion with family/friends about the timeframe of the pandemic (likely long duration)	Explanation of specific scientific concepts	
Directly mentions discussion with family/friends about social distancing		
Directly mentions discussion with family/friends about viruses being different to bacteria/antibiotics do not work		
Directly mentions discussion relating to misinformation/incorrect guidance (e.g. face masks)		
Directly mentions discussion with family/friends about hygiene measures		
Personal examples of preventative measures (e.g. keeping distance from family/friends)		
Noted compliance with preventative measures was inadequate in (all/some) aspects of society		
Noted personal compliance with preventative measures		
Noted compliance with preventative measures		

of student experience could not have been predicted as the pandemic unfolded), but our response analysis indicates that there is opportunity to construct appropriate yet flexible schemes.

Course content/information

Of course, much of the scientific information provided in the essays focused on virology and medical microbiology/epidemiology. In terms of how individual students used this information, the following broad observations were made: Fundamental information such as 'what is a virus' was typically mentioned first as information given to family (particularly) and friends. More nuanced detail included the fact that there were no specific treatments yet that specific antiviral agents were necessary and that it took some time to produce a vaccine. Epidemiological information included mention of asymptomatic cases, the duration of illness and the *R* value contributing to the shape and likely duration of the pandemic. Only one student mentioned contact tracing ('filiation'), but this is probably because the essays were written relatively early in the pandemic. In addition, it was clear that the basic information on disinfection and sanitization was especially helpful for the students in their attempts to explain scientific principles to their audiences. Translation of knowledge included information as to why enveloped viruses are destroyed by soap/detergent, information about aseptic technique applied to hygienic practice, the principles of disease transmission and filters related to the importance of masks, and the theory of disinfection and sanitization and the use of appropriate antimicrobials.

Considering more specific information, the lack of effectiveness of antibiotics, or antibacterial products, and the difficulties of developing specific antiviral agents were recognized and emphasized by many of the students (69 mentions in student essays). The inappropriate use of hydroxychloroquine (two students) was also mentioned. Several students mentioned mutation (18 students) and polymerase chain reaction (PCR) (7 students), noting in addition that they explained the importance of mutation in RNA viruses, the potential impact on epidemiology and vaccination, and so on. It is impressive that these relatively difficult topics were discussed with their families—although of course all of the students were studying molecular biology and genetics. Using Word 'finder' for particular words used in student responses, the words disinfection/ant and sterilization were each used in the essays 84 times; sanitizers 19 times (Fig. 1), demonstrating that key public health concepts are present in a significant number of instances throughout the student responses. However, it is important to note that the presence of a word does not indicate appropriate contextual information (*vide infra*).

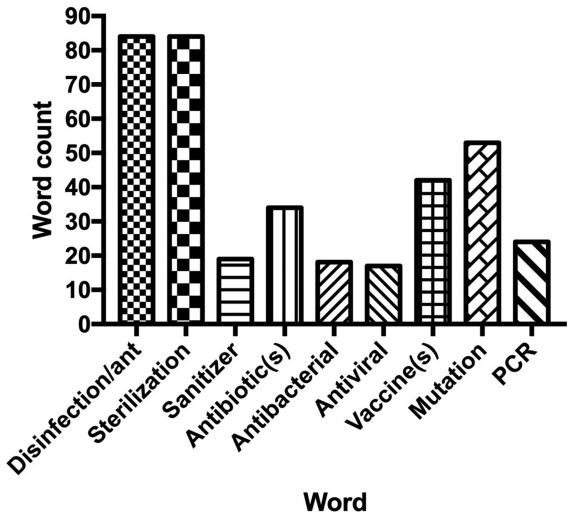

Figure 1. Frequency of word usage in student essays that focused on knowledge-based information that they used when informing their audiences during coronavirus lockdown.

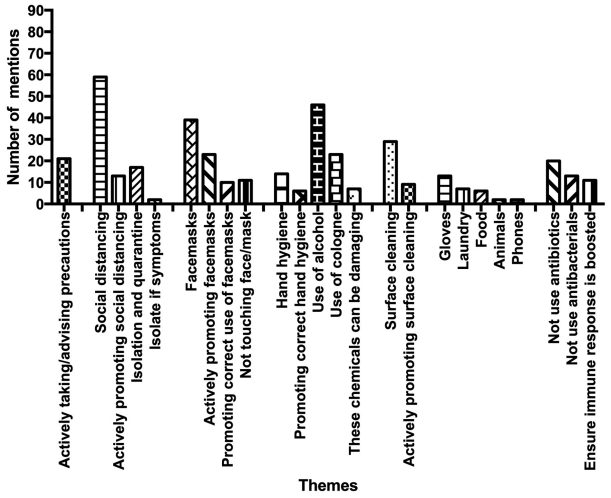

Figure 2. Using student essay responses and the detailed analysis of themes, key behaviours that were recommended during the coronavirus pandemic were noted by students. Behaviours around social distancing, wearing of face masks, hand hygiene and surface hygiene have been grouped together. Other common or interesting observations have also been included.

Behavioural change

The key behavioural changes asked of populations during the pandemic were reiterated in high numbers in the student responses (Fig. 2): social distancing, quarantine and isolation; the use of face masks and the importance of hand and surface hygiene, and to a lesser extent, glove wearing. The students adhered strictly to the rules, and were generally fastidious in actively ensuring that rules were followed correctly by others. Although this might be perceived as being 'obvious', the fact that all students were relating their microbiological knowledge to appropriate behaviours during a pandemic is an impressive demonstration of microbial literacy (Timmis *et al.* 2019). Counts of frequency of relevant words in student essays (e.g. hand(s), 114 (53); mask, 127) again provided data indicating student awareness on key public health interventions, but they were not helpful in our attempts to understand specific behaviours. Attempts to subdivide particular behaviours through word usage were similarly unhelpful (e.g. home, 57; quarantine, social distance(ing), 15 (13); quarantine, 18; 14 days/2 weeks, 9/3; isolation, 9).

It was fascinating for the UK reader to find out about 'cologne', a very common traditional fragrance/hand sanitizer (70–80% ethanol) used in Turkey that is kept in most households for hygienic purposes and is offered to guests, as a part of Turkish hospitality. Cologne was in high demand in Turkey during the pandemic (http://www.bbc.com/travel/story/20200407-turkeys-unique-hand-sanitiser). One student used their knowledge of the importance of ethanol as an antiviral agent to purchase aftershave (checking the ethanol concentration) due to a shortage of cologne. Another made their own disinfectant. There were some interesting additions to the more frequently listed behaviours, including correct laundry procedures, food sanitation protocols and, rather vaguely, the importance of maintaining a healthy immune system.

There were several examples given where students explained aspects of coronavirus epidemiology. They were often asked when the pandemic would end (19 students mentioned this), and also had to dispel the notion that incidence would fall when the temperature rose, bringing their knowledge of UV irradiation into their explanations.

Professionalism

A particularly impressive dimension to the essay responses was the mature way in which the students took on the responsibility of conveying information about appropriate behaviour to their audiences (Fig. 3). By scanning the essays and grouping subthemes within the topic of 'professionalism', it was apparent that the students' learning experiences had helped them with knowledge, understanding and application of relevant microbiology ($n = 49$). They also recognized that a lack of understanding amongst non-microbiologists affected their behaviour ($n = 41$). As noted above, many students were confident enough to answer questions and actively inform those who were not following the rules. They were keenly aware of regulations (over 65s and under 20s confined to home—two students), including self-isolation for 14 days when they returned home from the university (six students) as well as waiting for a few days for airports to become quieter (two students). Fifteen students overtly recognized themselves to be experts. Five students noted the psychological strain of living through a pandemic, and an additional three students noted their own anxieties related to their increased knowledge on the topic. The more quantitative focus on the frequency of word or phrases used reinforced many of these observations, albeit in a less nuanced manner: for example, the theme of social responsibility was identified on 30 occasions.

The theme of continuous learning was evident from many student responses ($n = 42$), with several students noting how their knowledge had helped them to follow research progress in the area, and to identify reliable sources of information, which in turn helped them to explain often difficult concepts to others, occasionally through blogs or social media. They also appreciated the difficulties of understanding complex terminology.

Conspiracy theories ($n = 33$) have been rife globally, and the students were very aware of their responsibility in helping to clarify misconceptions or 'fake news', for example about 5G, or bioweapons ('the disease is a zoonosis'), to emphasize information pollution or 'infollution' ('yellow journalism', 'fake news',

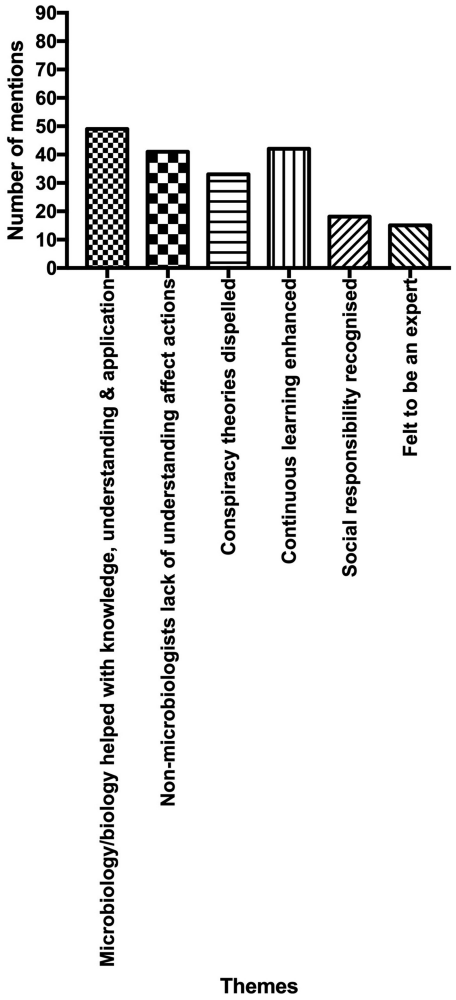

Figure 3. Themes relating to the students' sense of professionalism and their role as 'expert' were identified from their essays.

'clickbait'), and to highlight the 'absurdity of injecting antimicrobials' or drinking cologne. One student noted:

> 'learning the truth becomes harder.'

A pride in their choice of career became evident as the students practised their science (six students), along with some humility in acknowledging their own limitations (one student)—one student sadly felt that they had had 'no effect'. Some quotes in the student essays emphasized the more positive points, for example:

> 'I realised that society needed people like me more.'

> 'This pandemic period has improved my view of looking at everything differently than anyone else.'

> …'motivated me to study my lessons more and do more research about my field.'

Audience

As they returned home, the students' main audience for their 'science communication' was their family and friends. There were 133 examples where family was referenced (friends, 31; relatives, 10). This observation was confirmed using a word search. The theme of 'public health messaging' was noted on 160 occasions, demonstrating how the behaviour-focused practices were implemented.

General remarks

The authors are not aware of any similar study that has presented such an in-depth analysis of student essay responses, using both quantitative and qualitative approaches. Although it proved to be a laborious task, this work has revealed an impressive demonstration of student knowledge and its translation/application, science literacy and social responsibility, and we suggest that the practice of qualitative analysis in microbiology be considered more widely in educational research carried out by microbiologists (of course, social scientists are very familiar with such practices).

We believe this paper describes a scenario where rote assessment can be used to assess wider scientific literacy with respect to application in society, providing students with an opportunity to incorporate and apply their learning into real-life situations. This approach provides an interesting insight for academics who are looking for innovative modes of assessment, because our analysis has demonstrated that rote assessment need not be totally dismissed in assessing constructivist learning, conceptual understanding and impact on student behaviour. Instead, consideration can be given to constructing rote assessments that use real-world, timely examples (microbiology provides many such examples) around which students can apply their theoretical learning. Assessments that enable students to interpret their own experiences within the context of their knowledge base and changing external events provide opportunity for higher level learning, and this paper supports such a premise.

CONCLUSION

This straightforward examination assignment provides an excellent example as to how student knowledge affected their behaviour during coronavirus lockdown, and helped them to inform others, thus satisfying our original aim. The essay responses also, unusually, shed light on human aspects of disease epidemiology, rather than on the pathogen, and show how human interactions affect behaviours. These more personal dimensions are not usually addressed in students' scientific essays, and it was very heartening to read of their careful interpretation and application of the science that they had learned, and how they modified their behaviour and helped to inform and change the behaviour of others. The exercise could usefully be repeated in other assessment situations, allowing academics to explore the opportunities of rote assessment in conceptual understanding and constructivist learning, whilst allowing students to apply their knowledge to real-world events, and consider their own behaviours (scientific literacy).

As one student said:

> 'in nature, adaptive and strong creatures will live, so we need to adapt to this situation.'

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