Journal of the Foundation Year Network, Volume 6 (2023), pp. 91-97

Where Can We Find Time to Make, and Learn From, Mistakes?

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The foundation Science year at our university is a fast-paced course designed to cover the necessary fundamental content needed for progression onto a variety of life, health, and bioscience degrees while at the same time developing scientific skills and preparing students for undergraduate study. There is a constant thread of summative assessment across the year, leaving little time for formative assessment and feedback opportunities where students can make mistakes and learn from them. To address this, a programme-level approach to assessment has been adopted, resulting in the learning outcomes for more than one module being assessed within the same piece of coursework. Taking this approach has provided the opportunity to plan the provision of valuable time and safe opportunities for students to engage with formative activities moving forward. These formative opportunities will provide students with feedback that they can use to learn from their mistakes in time for the summative coursework assessments.

Introduction

This paper illustrates the use of a programme-level approach to develop 'combined' pieces of coursework and outlines the formative activities used to enable students to have a go, make mistakes and learn from those mistakes.

The Science Foundation Programme

The Science with a Foundation Year (SFY) is a one-year course primarily designed for those students who are not eligible for direct entry onto their chosen degree programme. The course provides the opportunity for students to gain an understanding of key subject concepts and develop the skills necessary for success at degree level. Therefore, for the majority of students much of the content is new and challenging and can seem very overwhelming.

The SFY course is made up of four compulsory modules and one optional module. The compulsory modules consist of Foundation Chemistry (40 credits), Mathematics for Foundation

Science (20 credits), Foundations of Scientific Research (10 credits), and Constructing Scientific Arguments (10 credits). The optional module is chosen from either Foundations of Human Biology or Foundation Biological Sciences (both 40 credits). All the content-driven modules (Biology, Chemistry and Maths) run parallel across the year with one of the skills-based modules in each semester. Figure 1 below provides a summary of the SFY.

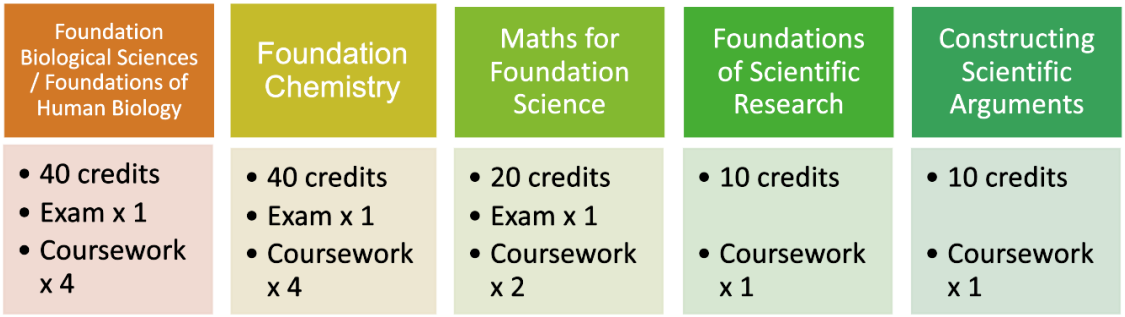

Figure 1: The modules, credit weighting and assessments that make up the Science with a Foundation Year Programme.

The structure and nature of the course presents several issues. The course is very fast-paced as it is designed to cover fundamental content for progression onto a variety of degrees whilst developing scientific skills and preparing for undergraduate (UG) study. This results in a very busy timetable with an average of 20-25 hours contact per week and a total of 15 assessments across the five modules. Overall, the packed timetable with a constant thread of summative assessment across the year (Table 1) reduces the opportunity for lower-stakes formative activities where students can gain useful feedback, learn from their mistakes, and feed-forward into improving their higher-stakes summative assessments.

Semester	**Summative Coursework Assessments**					
1	Chemistry CW1	Biology CW1	Biology CW2	Scientific Research CW1	Chemistry CW2	Maths CW1
2	Biology CW3	Biology CW4	Maths CW2	Chemistry CW3	Chemistry CW4	Scientific Arguments CW2

Table 1: The structure of the original assessment schedule for the Foundation Science programme, where all the assessments shown are summative.

Problems Associated with Over-Assessment and Modularisation

By its nature, modular learning can lead to over-assessment to ensure assessment of the modular content, which in turn places a focus on short-term retention as opposed to developing an in-depth synthesis of knowledge across topics (Tomas and Jessop, 2018). In addition, having a series of summative assessments can lead to students not having the time to put the necessary effort into each assessment, such that they may prioritise what they perceive to be the more important assessments over others, particularly if the deadlines fall closely together (JISC, 2016). A further issue with multiple assessments is that academic staff are often unable to return marks and feedback in a timely manner. Timely return of feedback is essential if students are to have the opportunity to productively engage with feedback and be able to develop and learn from their mistakes as they move forwards (for example, Nutbrown, Higgins, and Beesley, 2016).

Indeed, students have criticised the timeliness of feedback, which can often lead to an additional barrier for engagement with any feedback provided (for example, O'Donovan *et al*., 2019). These issues therefore result in either students not having the necessary feedback to learn from their mistakes in time for future assignments, or students not reading and acting on the feedback provided and so continuing to make the same mistakes moving forwards.

Modular learning also often results in students not being able to see the bigger picture of how the modules in the programme relate to each other, hindering their ability to integrate concepts from different modules (Treacy and O'Donoghue, 2013). This can particularly apply to the application of mathematical concepts elsewhere given that students are often taught mathematics in isolation throughout their education (Chi, 2021).

Introduction of Programme Level Assessments

To address the issues identified, a programme-level approach to assessment is being introduced. This involves designing assessments that summatively assess the learning outcomes from more than one module. One of these assessments directly links mathematical concepts into a scientific application through laboratory work, data analysis and interpretation. The other involves the production of a laboratory report that assesses the content from the Biology module alongside statistical testing from the Maths module. The learning outcomes assessed for the two pieces of integrated coursework are illustrated in table 2.

Coursework assessment	**Science learning outcomes**	**Maths learning outcomes**
Chemistry and Maths combined lab report	<u>Topic: Kinetics</u> (i) Rate laws and rate constants (ii) Rate constants and temperature	<u>Topic: Graphing</u> (i) Relationships between variables (ii) Linearisation of data
Biology and Maths combined lab report	<u>Topic: Culturing micro-organisms</u> (i) Using a microscope (ii) Techniques to identify bacteria	<u>Topic: Hypothesis testing</u> (i) Calculating and presenting descriptive and inferential statistics (ii) Using statistical software

Table 2: The learning outcomes assessed in the combined Chemistry and Maths coursework and the combined Biology and Maths coursework.

Overall, the redesign of assessments carried out for the SFY programme resulted in the removal of two separate assessments associated with the Maths module. Doing so freed up time for a formative assessment activity in semester 1 (Table 3) where students could develop their skills and learn from their mistakes prior to completing combined Chemistry and Maths summative coursework assessment at the end of the semester. This reduced assessment burden also provided students with more time to focus on all pieces of coursework and to engage with the formative feedback provided.

Semester	Coursework Assessments					
1	Chemistry CW1 (SA)	Chemistry Formative Assessment (FF)	Biology CW1 (SA)	Biology CW2 (SA)	Science Skills CW1 (SA with FF)	Chemistry CW2 & Maths CW1 combined lab report (SA with FF)
2	Biology CW3 (SA)	Biology CW4 and Maths CW2 combined lab report (SA)		Chemistry CW3 (SA)	Chemistry CW4 (SA)	Science Skills CW2 (SA)

Table 3: The structure of the assessment schedule for the Foundation Science programme during the 2022-23 academic year. Note: SA = Summative Assessment; FF = Formative Feedback; CW = Coursework.

Student Attainment and Perceptions

Given the major change associated with these assessments was the removal of independent, isolated Maths coursework assessments and the incorporation of the relevant Maths concepts into existing Chemistry and Biology module practical assessments, the student attainment for the Maths elements of the new assessments has been compared to previous cohorts who submitted isolated Maths assessments (figure 2). In previous years (2019-21), coursework 1 for the Maths module was focused more on the basic algebra elements of the content in mainly a mathematical context as opposed to a scientific context, although some scientific applications were used as examples. For the newly designed combined assessment replacing Maths coursework 1, the Maths concepts addressed involved the more complex concept of manipulating data through linearisation and the application and interpretation of logarithmic/exponential relationships. Maths coursework 2 had previously involved the isolated statistical analysis of a provided set of biological data so the only significant change here was that students carried out a statistical analysis on a biological data set they had collected themselves in the laboratory during a practical involving the culturing of micro-organisms found in pasteurised milk. A statistical comparison of the outcomes for each cohort using a pairwise one-way ANOVA including a Bonferroni correction (SPSS, 2021) indicates that there is no statistically significant difference between any of the cohort outcomes at the 5% significance level ($F = 0.819$ and $p = 0.485$ for coursework 1; $F = 0.751$ and $p = 0.524$ for coursework 2).

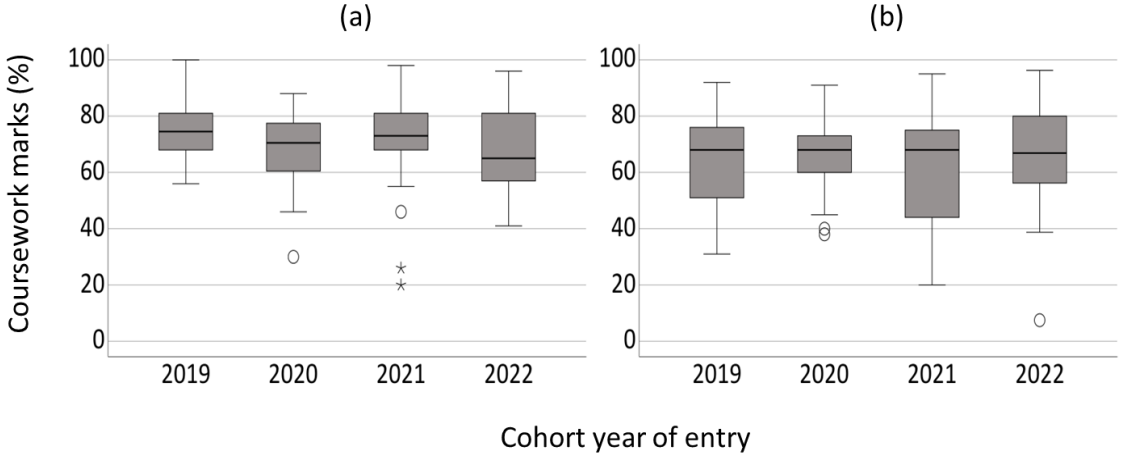

Figure 2: Box plots illustrating the student attainment (home students only) for the maths module coursework assessments from 2019-22 cohorts. (a) Range of student marks for maths coursework 1 and (b) range of student marks for maths coursework 2. The 2019-21 cohorts completed standalone maths coursework assessments (coursework 1 based on algebra; coursework 2 based on statistical analysis of a provided dataset) and the 2022 cohort completed the integrated science and maths assessments (coursework 1 based on graphing and linearization of scientific data; coursework 2 based on statistical analysis of collected laboratory data).

As part of the Student Evaluation of the Module (SEM) process carried out the University each year, the students are encouraged to provide extra written feedback, in addition to the basic Likert-style satisfaction ranking (Likert, 1932), that is constructive and can be used for future development of the modules and programme. There were several comments that referred directly to the newly combined assessments. These comments mainly identified the benefits of applying Maths in a context that is useful and appropriate to the students and how this helps them understand the content more clearly. There is less acknowledgement of the reduction in coursework assessments, however, this is not surprising given that students had not experienced the previous coursework schedule. Some example student comments are provided below:

> "The maths/biology lab report was a good way to incorporate the link between maths and biology"

> "Integrating mathematics into biology and chemistry coursework I found generally very effective to embed key concepts from logarithms and statistics specifically."

> "I like the integrated coursework because it puts the maths content into scientific context, which I think is useful and beneficial to me. Also it makes it feel like there is less coursework, even if it is a longer piece. So it makes the workload feel more manageable."

> "I think the combined coursework is beneficial as it's how we would use the maths content on our courses and makes maths coursework sounds less daunting."

> "I thought integration of the maths module in chemistry and biology was quite helpful in helping me understanding the content more clearly."

Reflections and Next Steps

The introduction of combined science and Maths assessments has not affected the Maths assessment attainment compared to previous years, despite the first piece of coursework that combined the Maths topics of graphing and linearisation with chemical kinetics being more complex than the topics assessed in the semester 1 coursework from previous years (figure 2). In addition, the embedded assessment of Maths was well-received by the students as they felt it enabled them to understand how Maths is used in science and they appreciated the reduced number of summative assessments.

However, it was identified that students still needed a significant level of support with the Biology and Maths summative coursework assessment in semester 2 even after completing and receiving feedback on both the formative activity and the Chemistry and Maths coursework assessment completed in semester 1.

Consequently, a further reduction in Chemistry and Biology assessments is planned to create additional space in the timetable for more formative assessments that will enable students to learn and practise how to write and present specific parts of a laboratory report and then reflect upon their 'mistakes' in preparation for the summative report in semester 2. Table 4 illustrates the new planned assessment layout. It is hoped that students will respond positively to the opportunities available via the formative activities and indeed use these to learn from any mistakes that they make and improve these in the summative assessments.

Semester	**Coursework Assessments**					
1	Chemistry CW1 (SA)	Displaying and interpreting lab results (FF)	Biology CW1 (SA)	Writing methods (FF)	Chemistry (CW2) and Maths (CW1) combined lab report (SA with FF)	Science Skills CW1 (SA with FF)
2	Writing an introduction and discussion (FF)	Biology CW2 (SA)	Reflection session on all FF	Biology (CW3) and Maths (CW2) combined lab report (SA)	Chemistry CW3 (SA)	Science Skills CW2 (SA)

Table 4: The structure of the proposed assessment schedule for the Science with a Foundation Year Programme. Note: SA = Summative Assessment; FF = Formative Feedback; CW = Coursework.

Acknowledgements

We are grateful to the Science FY students for providing feedback on their experiences.

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