Life Sciences Case Study 1 – Level 5	
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Setting	Second year module (Level 5) in a Life Sciences Department (module title: 'Communication and Analysis in Science'). The module aims to introduce students to methods and strategies for developing testable hypothesis, designing and carrying out experiments and analysing the data obtained.
Cohort Size	63 students
Rationale for using the Toolkit	This module aims to introduce students to fundamental research and data analysis methods in the life sciences. Typically, students who have taken science A-Levels or GCSEs may be familiar with basic concepts in experimental design, such as sampling, controls and the notion of a 'fair test'. However, they are often taken aback by the number of decisions that have to be made when designing an experiment to the standards required in actual research. This module therefore typically presents a significant amount of 'troublesome knowledge' linked to threshold concepts that are key to preparing students for the significant freedom they have as researchers and therefore also the competencies they will need to carry out independent research for their final year dissertation project. The Traffic Lights Toolkit was previously used in this module to help design more effective teaching, but in this instance the intention was to integrate the Toolkit explicitly with an assessed activity for which the students had to develop a number of research-relevant skills. The Toolkit was adapted and design to scaffold student reflection and awareness of the skills they needed to develop as they carried out a practical activity and completed a log book with a record of their work as part of their summatively assessed coursework.
Learning activity	The module contains a series of six two-hour sessions in which students were asked to work in small groups (two to three students each) to design, carry out and report on a simple laboratory experiment. Students were provided with a list of materials and equipment they could use to design an experiment of their choice. This provided students with a lot of freedom, but also required them to think 'like a scientist' and make decisions on critical aspects of experimental design, including what variable(s) to measure and how to measure them accurately, how to ensure sufficient replication, how to risk assess their proposed protocol of work and how to make sure the hypothesis they aimed to test was aligned with the experimental design. Thus, this learning activity required students to develop several new and applied skills and represented their first experience of working independently toward a research aim. Students had six sessions two hour sessions (one briefing, five sessions to develop and execute the experiment), so were required to develop and apply these skills in a very short period of time. The learning experience was specifically designed to prepare students for their final year dissertation project, which would require them to use the competencies developed during this learning activity. The skills learned were summatively assessed via an online research log book for which students had to complete weekly entries.
Traffic Lights Toolkit	Perception of Challenge Tool (with numerical rating column), Rating Scale Tool

elements used	
Mode of delivery	Digital (Excel spreadsheet). The Traffic Lights Toolkit (Perception of Challenge Tool; POC and Rating Scale Tool; RT) was delivered as part of the summative assessment for this learning experience by being integrated into the online log book students had to complete.
Number of engagements with the Toolkit	4
Aims	The POC included statements relating to the skills students were to develop and that were being assessed. Reflection is an integral process in designing experiments and optimizing experimental design as well as in the process of analysing and interpreting experimental results, so asking students to engage with the Toolkit was intended to signpost the required skills for students, encourage reflection on new skills learned on a weekly basis as well as on the experience of designing, executing and analysing the results of an experiment overall. The PoC tool was included to facilitate this process. In addition, students were encouraged to use the tool to identify skills they were already confident in and skills for which they lacked confidence, therefore allowing them to identify where they needed support from lecturers and instructors during practical sessions. The RS Tool was chosen to help students articulate and concretize this process for one skill in particular that they had particularly low confidence in. The Toolkit was integrated into the summative assessment to provide structure to the engagement with it and encourage engagement.
Methods	First use of the Toolkit: Students were briefed on the assessment and the schedule for the practical sessions for one hour. In the following hour, they were then briefed on the POC and RS Tools and the aim of including them as part of the summative assessment. Students were told that they would be assessed on their engagement with the Tools, not on the content of the Tools they completed. Students were introduced to the online log book (on PebblePad) in which the Tools were integrated as the downloadable template spreadsheet available with this document. The POC Tool had twelve statements, grouped by the themes 'Project preparation' and 'Project execution' (Table 1). For each statement, the POC Tool included a space to indicate the traffic light colour, a space for adding a numerical confidence rating (1-10) and a space for notes, thoughts and comments. There was one RS Tool included in the spreadsheet, for use with the lowest-rated statement. The use of the POC and RS tools were explained and students were then asked to complete the first copy of the tool as part of the briefing session. They had approximately half an hour for this activity. They were encouraged to reflect on their confidence levels at the moment and were encouraged to add any notes, thoughts and comments in the provided spaces so they could articulate for themselves and for the lecturer/instructor why they felt a certain way. Students were then shown how to upload their completed tool to the online log book and were asked to do so before they completed the session.

Table 1: List of skills statements included in the Perception of Challenge Tool. Statements marked with an asterisk were grouped under 'project preparation', other statements were grouped under 'project execution'.

1. I can turn a research question into a specific, testable hypothesis.*
2. I can design an experiment or project to test the hypotheses I have generated.*
3. I can think of a suitable control for my experiment.*
4. I know what variables to measure and what measuring device to use to gather the most accurate and precise data.*
5. I can decide on an effective and practical sampling strategy (e.g. sample size, randomization).*
6. I can write a protocol for my project that is clear and detailed enough so others can replicate it.*
7. I can think of factors that might prevent me from completing my project as planned and can think of alternative approaches.*
8. I know how to use the laboratory equipment, reagents, software etc. needed to complete my project.
9. I understand the procedures around risk assessment and chemical safety relating to my project.
10. I can work effectively with the others in my group in preparing and completing the project.
11. I know what to do when a piece of equipment is difficult to use or not working as expected.
12. I can think of suitable basic analyses that will allow me to test the hypothesis (or hypotheses) of my experiment.

Subsequent uses of the Toolkit:
As part of their online log book, students were required to complete and submit additional spreadsheets with the POC and RS Tools once they had completed entries in their online log book for the second, third and sixth week of the subsequent practical sessions. Each spreadsheet coincided with the development of skills. In week 2, students had to originate a research question and derive from it a testable hypothesis as well as propose a measurement and sampling strategy. In week 3, students had to compose a protocol for their experiment and submit a risk assessment. In weeks 3 and 4, students had two hours each week to carry out the experiment. In week 5, students had to provide comments on a) their reflection on their experience and what they had learned, b) a suitable approach for data analysis, c) an interpretation of the data they

	had obtained, and d) suggestions for future research based on their experiment.
Sharing and evaluating outcomes	Students had access to their own sheets at all times during the project, so were able to assess their progress and growth in confidence by comparing newly completed sheets to those completed previously. The data from the submitted POC/RS spreadsheets were anonymized and compiled and presented to students in the second to last week of the module to support discussions looking ahead to their final year dissertation project as well as exploring the general principles and utility of reflecting on learning and identifying strengths and weaknesses. Students were invited to comment on their experience with the Toolkit in the style of a focus group and at the beginning of this session, students in attendance were asked to complete a questionnaire on their experience with the tool.
Outcomes	Engagement with the four Toolkit sheets was high. 95% of students who completed the assessment (63) also completed at least one of the tools and 57% of the students completed all four Toolkit sheets. In general, all students reported an increase in confidence for most or all of the skills statements included in the Perception of Challenge Tool. This is illustrated by the 'confidence map' that compiles green, amber and red colour indicators provided for each statement by students (Fig 1). Confidence levels at the beginning of the practical sessions expressed by the mean numerical rating of all skill statements for each student were not linked with increased attainment in the assessment as reflected by the summative mark (Linear regression analysis, $P>0.05$; Fig 2). A student's change in mean numerical confidence rating from the first to the last Toolkit sheet completed also were not linked with attainment (Linear regression analysis, $P>0.05$; Fig 3). This means that neither initial confidence levels or confidence gains during the practical sessions had an impact on how well students did in the summative assessment linked to the learning activity to Toolkit was supporting. This outcome may seem unexpected, but since high-achieving students can be highly-self-critical and dismissive of their skills and abilities and low-achieving students may overestimate their abilities, this lack of a direct relationship between confidence levels and achievement is not surprising.

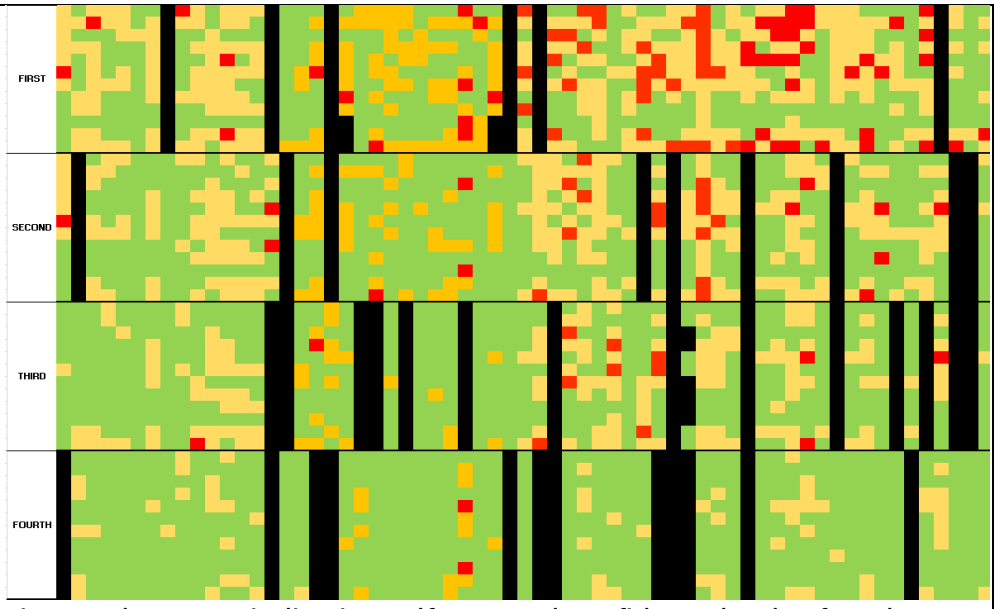

Fig 1: Colour map indicating self-reported confidence levels of students in relation to twelve skill statements across four separate engagements with the Perception of Challenge Tool. Green = Confidence, Amber = Challenge, Red = Stress/Anxiety. Each column represents one student, each row one statement. The responses to the four Toolkit sheets are separated by bold horizontal lines. Black squares indicate missing data. N = 55 students.

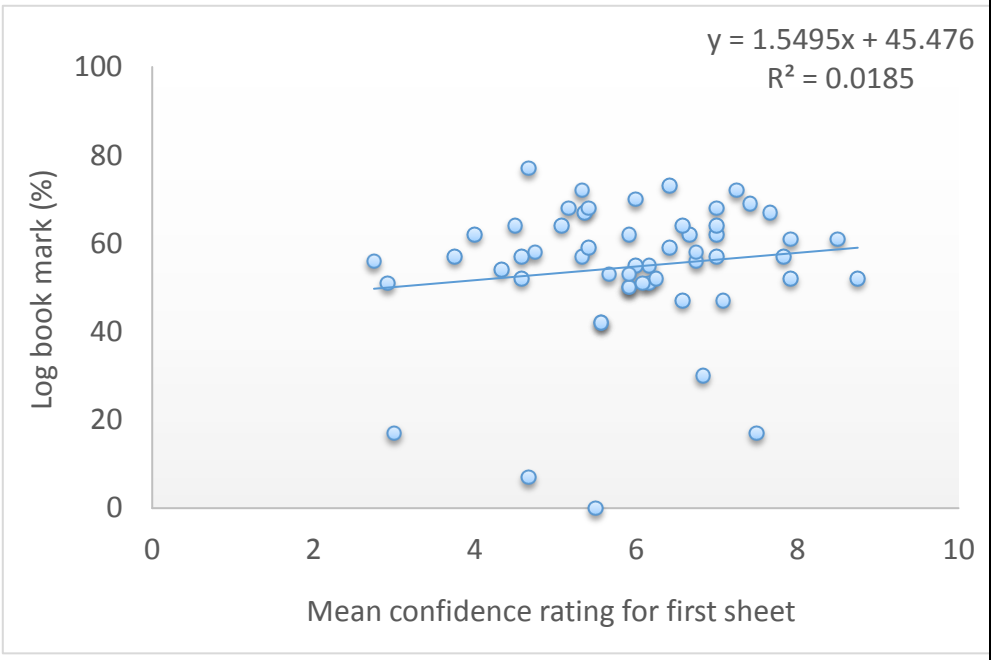

Fig 2: Linear regression of mean confidence rating per student (mean of responses to all statements on first sheet) against assessment mark. Line indicates linear fit (Coef: = 1.55, F < 0.01, P = 0.971; N=55).

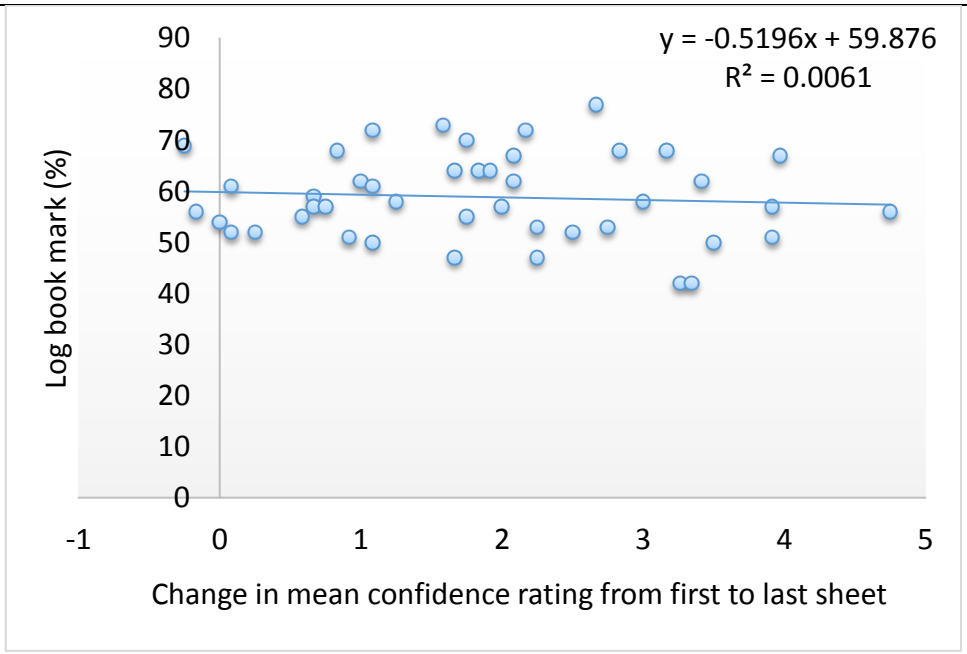

Fig 3: Linear regression of confidence change per student (mean of differences in responses between first and final sheet) against assessment mark. Line indicates linear fit (Coef: = -0.52, F = 0.26, P = 0.614; N = 43).

However, there was evidence to suggest that greater engagement with the tool – and therefore possibly also greater reflection scaffolded by the Toolkit - was linked with higher achievement in the assessment. When marks for the assessment were grouped according to how many of the four Toolkit sheets a student had completed, there as a consistent and significant trend for students who completed more of the sheets to have achieved higher marks (One-way ANOVA with Tukey's test, $P<0.05$; Fig 4). This may not necessarily be indicative of a causative relationship as students who are more engaged also tend to achieve better outcomes in higher education. To further investigate the link between student reflection with the Toolkit and attainment, the mean number of characters students had entered into the space for qualitative comment per Toolkit sheet were correlated against the marks attained. There was a weak but significant positive relationship – the more students had written in relation to their feelings and thoughts about each skill statement, the higher their grade (Spearman's rho = 0.312, P = 0.014; N = Fig 5).

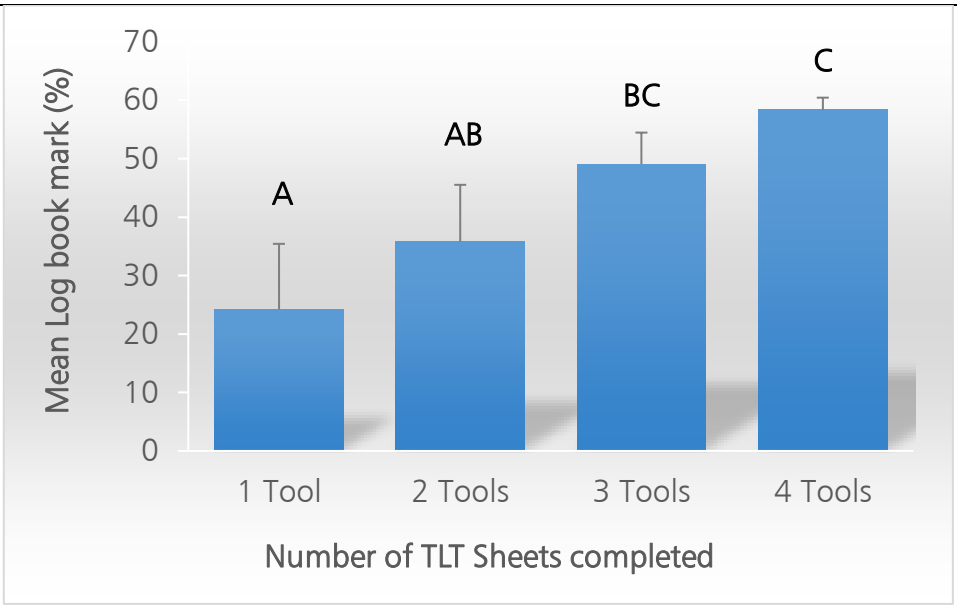

Fig 4: Mean assessment mark (+SE) achieved by students completing one, two, three or four of the Toolkit sheets during the assessment. Bars that do not share the same letter are significantly different from each other (Tukey's post-hoc test, $P<0.05$). N= 4, 7, 15, 35 respectively.

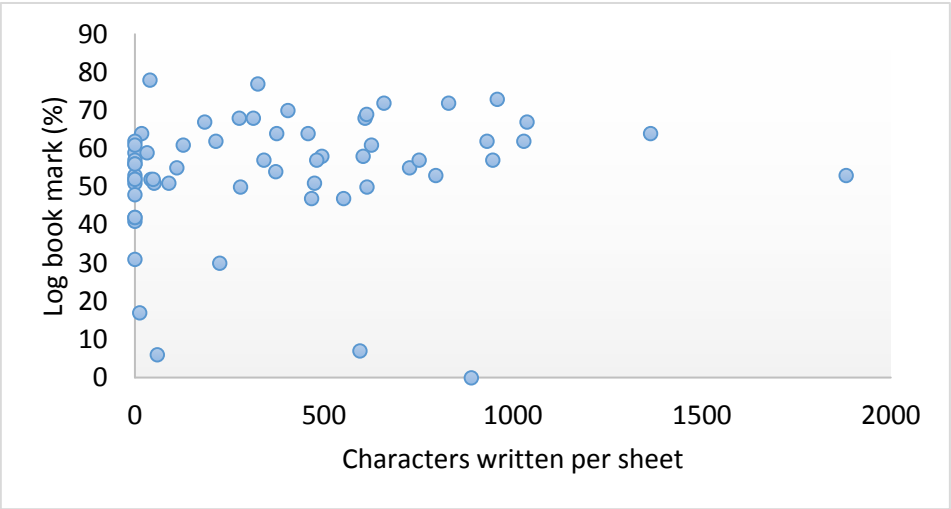

Fig 5: Correlation of number of characters written by students in space for reflective comment against assessment mark. N = 62.

The qualitative comments made by students about the skills statements often expressed directly or implied barriers to learning as well as enablers of learning. These were compiled into a list (Table 2) and will form a valuable resource for future curriculum development and course delivery as many of these barriers and enablers were common among students and therefore can be addressed proactively by adopting approaches to teaching that scaffold where barriers exist and reinforce enablers.

	Table 2: Barriers to learning and enablers to learning as expressed by students in the space provided for qualitative comments on the Perception of Challenge Tool and Rating Scales Tool. Barriers / Enablers Lack of experience — Confidence Lack of confidence/skill/ability — Receiving Guidance/Support from lecturer/technician/instructor Learning disability — Guidance/review from peers General anxiety — Planning ahead Fear of the unknown — Practice/ experience Self-criticism — Individual research/study Time management — Time Past negative experiences Lack of motivation Social circumstances Lack of infrastructure/resources Lack of peer engagement In summary, while the confidence rating and assessment data from the Toolkit sheets themselves only provide limited evidence of a direct and causal relationship between engagement with the Toolkit and improved attainment in the linked assessment, there is strong evidence that students were able to see an improvement in their confidence levels and identify for themselves and their tutors a number of barriers to learning as well as enablers of learning.
Student perceptions and feedback	Of the students who completed a questionnaire about their experience with the Traffic Lights Toolkit in this module (N=16), a majority expressed positive views towards the Toolkit and its benefits for them (Fig 6). For example, approximately 85% of responding students agreed that the Tools had helped them to identify areas where they needed support. Almost as many students agreed that the Tool had made them more aware of their role as an active learner, a key aspect of the Toolkit and one of the transferrable skills that were developed during this learning activity. Approximately 85% of students agreed that the Toolkit had helped them improve their assessment mark and almost all of the respondents were supportive of the tool remaining a part of the assessment for future students (Fig 6).

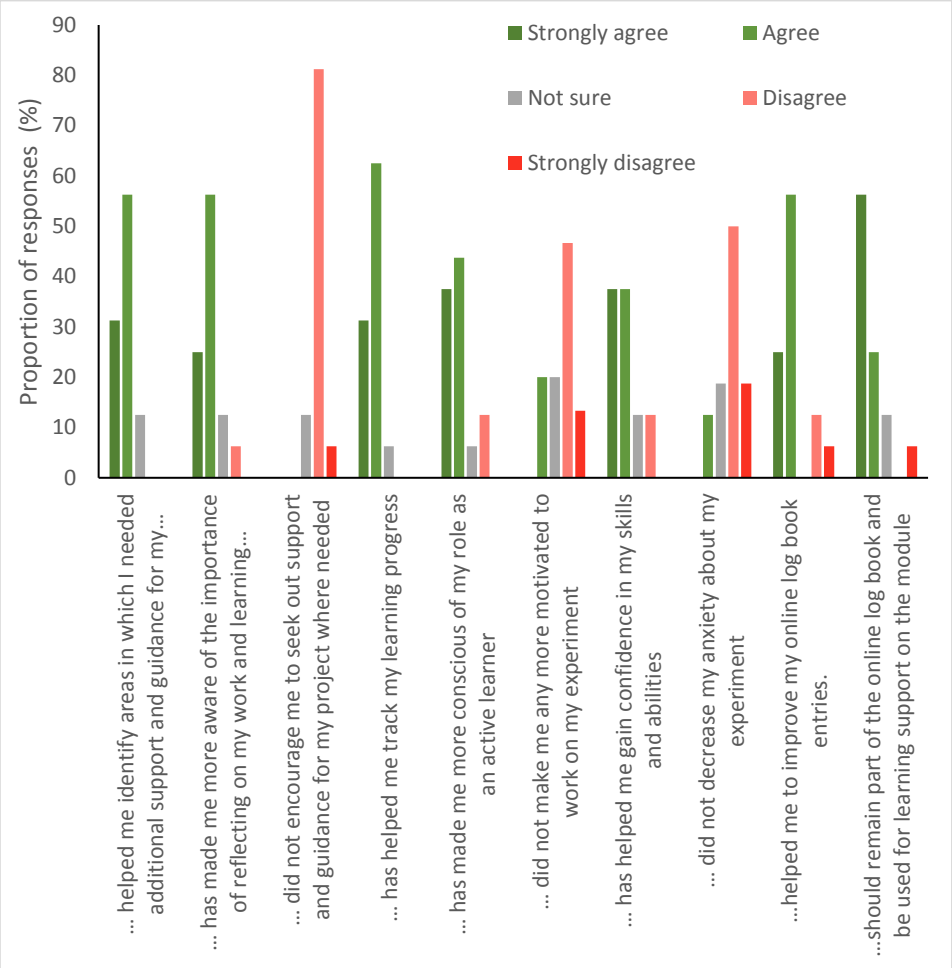

Fig 6: Student responses to questionnaire evaluating their experience with the Traffic Lights Toolkit. (N = 16)

In the questionnaire, students were also asked to further comment on any positive or negative responses they had given and suggest changes and/or improvements to the Toolkit. Similarly to the feedback provided by Allied Health students in one of the other case studies run as part of this project, themes that emerged from these comments were that the Toolkit had helped students to externalize their perception of themselves and their learning (e.g. "The colour scheme of the traffic lights tool allowed you to visually see what you're doing well at."). This leads to a perspective shift (e.g. "[The toolkit] allowed me to think about things that I wouldn't normally consider when reflecting on my work. However, these are things that I should think about and have helped me to complete the project thoroughly."). Students reported using the tool to sort and map their abilities and learning needs ("It broke down the areas that I needed to improve [on] - I found this really helpful as it then could fairly easily form the basis of a checklist of skills to work on, meaning they seemed like achievable goals!"). As a result of this process, students reported an intrapersonal change ("Solely focusing on one issue and realising that I am improving gave me more confidence in my experiment and reduced my anxiety."). Some students also made some very interesting comments suggesting improvements to the way the Tools were used: "I think there could have been a couple of blank statement

	boxes so we could put our own targets in there."; "I think maybe the traffic lights tool could be different for each week. […] If they were tailored to what we had done each week, I think it would be even more effective at getting students to reflect on their work.". In the focus group discussion at the end of the module, after the results for the group as a whole were shared with students in attendance (N= 22), students expressed vies that echoed those made in the questionnaires. An avenue of discussion that was pursued in particular was whether the Toolkit encouraged students to be more reflective in their work and studies for this module, especially in light of the benefits this seemed to have for students in terms of performance in the summative assessment. Those students that said they were already reflective also tended to say that they were typically very critical of their own performance and that this caused them anxiety. They commented that the Toolkit helped them manage that anxiety by helping them to focus on specific skills for improvement and especially to track their progress and visualize their growth in confidence ("I found it really helpful to keep track of how I was doing and how my confidence was growing."). Asked whether the Toolkit made them think differently about what they were doing, one student commented that the Toolkit made them think differently about themselves and second-guess their initial levels of competence and confidence ("The Tool made me think more about each skill and how confident I really was about it. At first I would have said that I was really confident at coming up with a hypothesis, but the Tool made me stop and think about it a bit more and realize that maybe there was more to [that skill] and it was more complicated than I originally thought."). The same student also commented that the Tool increased their anxiety, however, as it made them think of all the work that lay ahead of them. When asked whether students felt that the Toolkit allowed them to articulate and express thoughts of inadequacy or where they needed help, there was general agreement. One student commented: "What I found really helpful was that when we filled in the Tool and were talking about it and also seeing the results now it showed me that I'm not alone and that other students feel the same way at the beginning of a module." Several students also specifically mentioned the Traffic Lights Toolkit as one of the most positive and useful elements of the module on module evaluation forms at the end of the module, even though the form contained no mention of the Toolkit.
Outlook	Large amounts of data and student responses originated from this case study and provide opportunities for extensive further analysis and interpretation. This analysis will continue into the future and will inform future iterations of the Toolkits and its use. This cohort of students was the last for the module in which the Toolkit was used for this case study. However, because of the positive impact the Toolkit has had on student learning and the way it has encouraged reflection in students, discussions are already underway to integrate the Toolkit and a similar assessment into one of the modules for Level 5 students on the new suite of science programmes at Canterbury Christ Church University.