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# How to Bridge the Gap that University Teaching Staff Face when it comes to Sustainable Chemistry Education?

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## Abstract
This research was conducted at Imperial's Chemistry Department. The purpose was to bridge the gap that teaching staff face when it comes to sustainable chemistry in higher education. This was done through, student survey, staff interviews and survey. The data from the student survey showed a definite interest from students in sustainability and an awareness to the urgency of the climate crisis. Specific modules (lecture and lab based) were identified as potential areas where more sustainability could be imbedded in the curriculum. Staff surveys are still underway, and the interview data can only be shared internally so does not feature in this report. From all this data overall, future changes can now be made to the curriculum and hopefully a start to this will be taking place this coming summer 2025.

## Introduction
Chemistry has always been considered as a central science because of its breadth and how it links to so many other sciences such as physics, biology and geology. This means that studying chemistry, should give you the opportunity to touch on so many different issues that we face in the world today. Indeed, if we look at the 17 Sustainable Development Goals (SDGs) that have been set out by the United Nations (UN), the subject of chemistry can help tackle most if not all those issues. However, it does not seem to be highlighted explicitly in the educational curricula at a school level[1] but also in higher education at university. In fact, there is a gap that exists between student expectations of sustainability content vs the reality. It is therefore important to understand the existence of that gap and find a way to bridge it, which is what this research aims to do.

## Methods
### Surveys
This research included two surveys, one that was intended for all undergraduate students at Imperial's Chemistry Department, and the other one was intended to all academic staff. Ethics approval was sought for both and they were made using Qualtrics and are anonymous. Details of questions will be added onto the appendix.

The student survey is currently closed and was open from end of June till the end of September, giving students the chance to respond while they were on summer holidays so as to not disrupt their studies. The communication was done via email from Dr Laura Patel, and via WhatsApp group chat by me with several reminders in both cases. The survey was analysed with thematic analysis.

The staff survey was open in the end of September and will be until the end of January, giving staff the opportunity to fill it out whenever suits them best in a long period of time to allow for flexibility. The communication in this case is done solely via email from Dr Laura Patel and there will be monthly reminders about it. The survey has not been yet analysed as it is still open, but thematic analysis will also be used.

[1] Green shoots: A sustainable chemistry curriculum for a sustainable planet. Royal Society of Chemistry n.d. https://www.rsc.org/policy-evidence-campaigns/environmental-sustainability/sustainability-reports-surveys-and-campaigns/a-sustainable-chemistry-curriculum/.

**Interviews**

The staff interviews were conducted via Microsoft Teams. They varied in lengths but were on average 45 minutes long. The questions asked varied on the expertise and role of the individual being interviewed, but there was a subset of generic questions that were asked to everyone. Since ethics approval was not sought for these interviews, results will not be shared in this report, however the questions will be added onto the appendix. The answers were also analysed using thematic analysis.

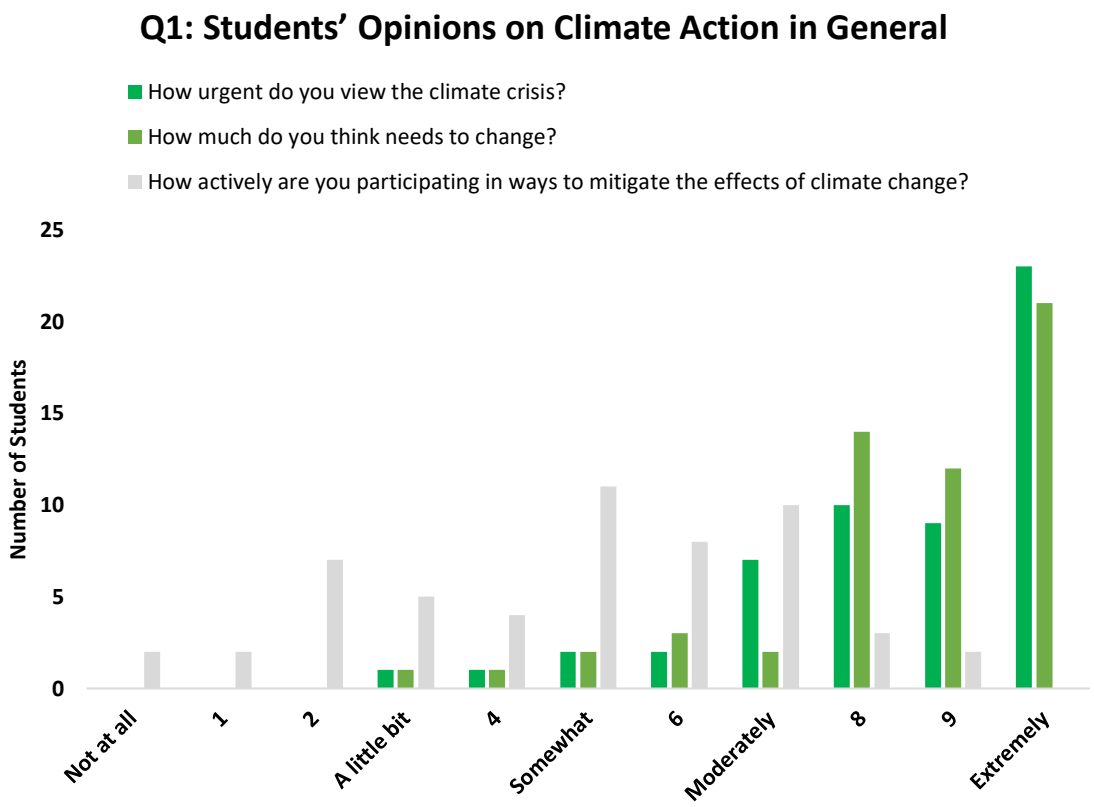
**Thematic Analysis**

As mentioned, thematic analysis was used to analyse the data that was retrieved from the surveys and interviews. This means that the approach was qualitative and that themes were being identified from the answers rather than before investigating them.

## Results and Discussion

This report will touch on 62 answers of the student. The survey was divided into three sections with opinions on: 1) climate action and sustainability, 2) students' current curriculum and 3) sense of agency within students' degree course. The detail of the questions for the survey as well as the free text answers will be included in the appendix. In the below sections, qualitative data was summarised with graphs, whereas quantitative data was summarised with tables.

### 1) Climate Action and Sustainability

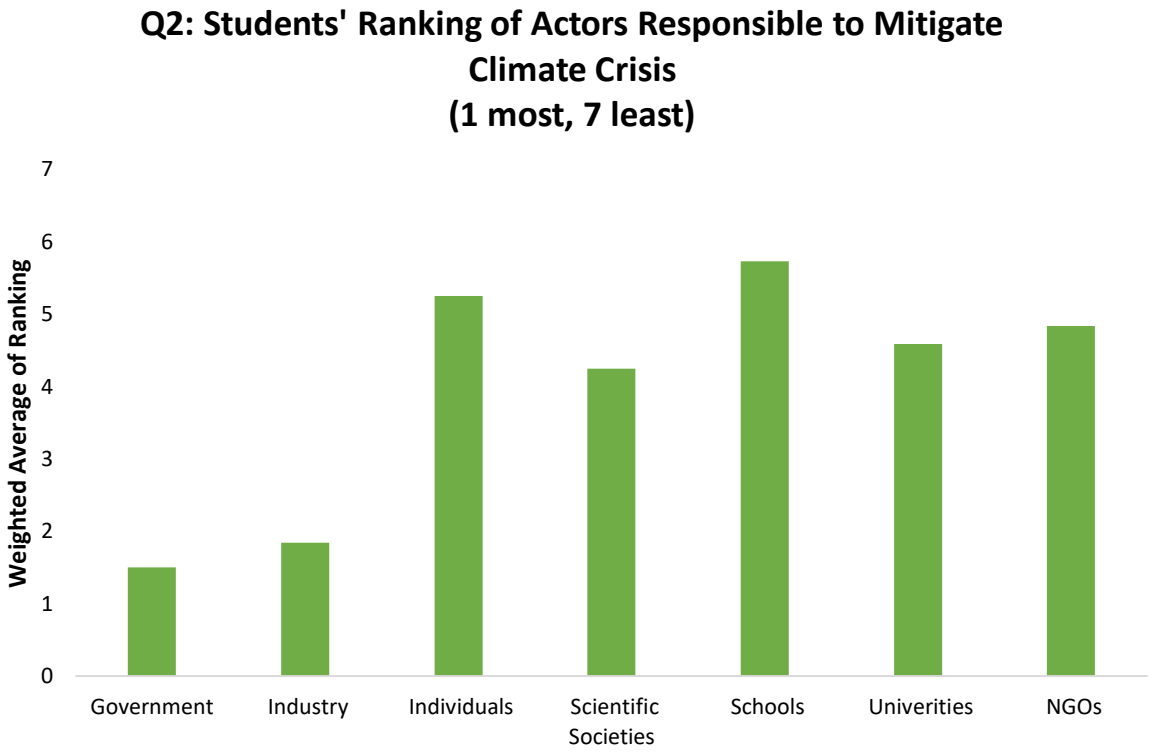



Q1 Summary Histogram

Majority of the students (88%)[2] believe that the climate crisis is urgent and that there is a lot that needs to change. Most students however (67%)[2] do not report engaging in a lot of activities to mitigate the crisis but rather they say that they do so mostly "moderately".

While there may be some bias as to who is answering this survey being more likely to care about the climate, the large number of people who have completed it is still reflecting a good proportion of 15% of students in the department. This shows some incentive and possibly some motivation to include more related topics into the curriculum.

The vagueness of the third statement was deliberate, but it may have confused students and made it harder for them to assess their own activity due to the lack of reference point. It is also not a good measure of their actual actions; they may be doing more than they say or less. The i-Engage module[3] might be an area to discuss this topic further, seeing how much students are "engaging" with the idea of being more sustainable.




Q2 Summary Histogram

When asked to rank who they believe should be most responsible actors in mitigating climate change, the majority of students ranked the government and the industry as the highest actors.

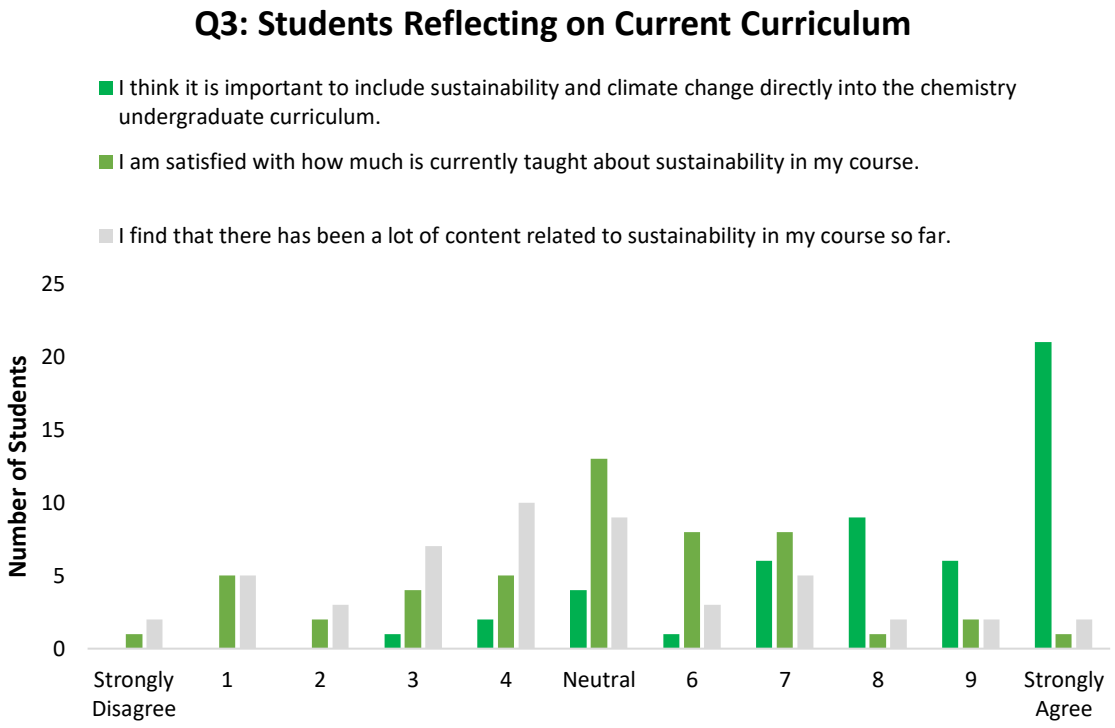
[2] Calculated by considering answers that were between "moderately" to "extremely". Similar method of calculating is used throughout this report.

[3] Pass/Fail module in 1st and 2nd year teaching different topics such as research techniques, self-reflection, action on EDI, making infographics and others.

Unsurprisingly, most students ranked individuals as the least responsible, this might be why many have answered in the previous question that they are not very proactive about mitigating the climate crisis. It may also be that they do not see their own agency in the world and in particular when it comes to this issue.

The factor we are interested in in this study is where students ranked universities, it seems to be around the middle ground, not the most responsible but not the least responsible either. This data is different than that from a student survey on sustainability by the Times Higher Education[4], where they received 3151 responses from prospective international students. According to that, "86% of students see universities as having an important role to play in achieving the SDGs, a similar proportion to those that see governments, society and businesses having an important role to play." This might be as the climate action is technically only one part of the SDGs, so students are thinking of it from a different angle. However, it also might be due to the different demographic. This survey did not ask students whether they were international or not, but it might have been a factor influencing their answers. It could also be due to how they were prospective students already thinking about sustainability before going to university, making their answers somewhat biased. It would be interesting to look at similar data in the future, perhaps from personal statements and interviews.

### 2) Current Curriculum




Q3 Summary Histogram

[4] The Impact of Sustainability on International Students' Study Choices: Findings from a Survey of 3,151 Students'. Student, 28 Apr. 2022, https://www.timeshighereducation.com/student/students-sustainability-survey.

From this data, we can see that most students, 86%, do think it is important to include the topics of sustainability and climate change directly into the curriculum.
Furthermore, only 40% of students are satisfied about how much is currently taught in their course about sustainability. With 28% of students only stating that they find there is a lot of content related to sustainability in their course so far.

The answers to this question clearly show the gap that exists between the student expectation and satisfaction.

It is worthy to mention that about a quarter of the students answered almost "neutrally" about whether they are satisfied with the sustainability content. This highlights that there may not have formed their own opinions on the matter or that they found it a bit difficult to answer, and being "neutral" was another way to say "I don't know" or "N/A" as they were not options.

It is possible that students only have a superficial understanding of sustainability, hence why they are very certain about it being important in the curriculum but not so sure about their satisfaction with the content. It could also be that students are not used to thinking about the content of their curriculum in this way.

**Q4: Please describe examples of where you have encountered content that you consider to be teaching you about sustainability. (Consider lectures, labs, workshops, tutorials etc...)**

In terms of labs:

| | Green chem lab assignment | Hack-it Lab[5] | Labs in general | Other Labs | Total[6] |
|---|---|---|---|---|---|
| **Total Frequency** | 12 | 5 | 7 | 3 | 27 |

In terms of lecture modules:

| | Sustainability Module | Macromolecules and Materials (MM) Module | Specific Lecturers | Other Lecture modules | Total[6] |
|---|---|---|---|---|---|
| **Total Frequency** | 3 | 5 | 3 | 10 | 21 |

The most common topic that students have recalled when thinking of labs or lectures where they learnt about sustainability is the Green Chemistry Assignment that they complete in 1st year. It is a reflective work they do in which they have to assess how green one of the previous experiments they have done was and then find alternative to that practical.

[5] 1st year lab group project, sometimes in collaboration with start-ups, to come up with sustainable solutions.
[6] The total does not necessarily represent the total number of answers as some may have mentioned more than one theme. (Same applies for other tables as well)

A fair number of students acknowledged it being highlighted within lab practices in general. This is suggesting that at least students are picking up on the way the practical sessions are run, in contrast to lectures where if the content is not directly mentioning the word sustainability it might be hard to make the links. Indeed, this is shown by the modules and lectures that students have decided to highlight, there is not as high of a number mentioning one specific module because students are at different stages of their degree (and done different modules). For example, Sustainable Chemistry is an optional 4$^{th}$ year module, so it is possible not many students have done it. However, this difference is also likely because what students take away from a lecture is very subjective unless it is clear and evident such as in the "Sustainable Chemistry" module. So, it is dependent on how much an individual is actively seeking out any indirect reference to sustainability, for them to be able to identify it in the lecture modules.

This is also true about labs as for example one student has stated that they have seen sustainable practices in the lab when it came to restrictions on the use of acetone, but they followed that up by saying *"though likely safety oriented"*, further emphasizing the point that the reason for the lab practice is not clearly communicated to students or if it is, it is not obvious enough to them. It might be useful to tailor the lectures and labs learning objectives to explicitly consider sustainability.

**Q5: Are there any specific topics in sustainable chemistry that you are interested in knowing more about?**

| | Lab related | Industry Related | Related to existing modules | More Holistic | Specific Techniques | Other Specifics | Total |
|---|---|---|---|---|---|---|---|
| **Total Frequency** | 4 | 3 | 4 | 5 | 7 | 3 | 26 |

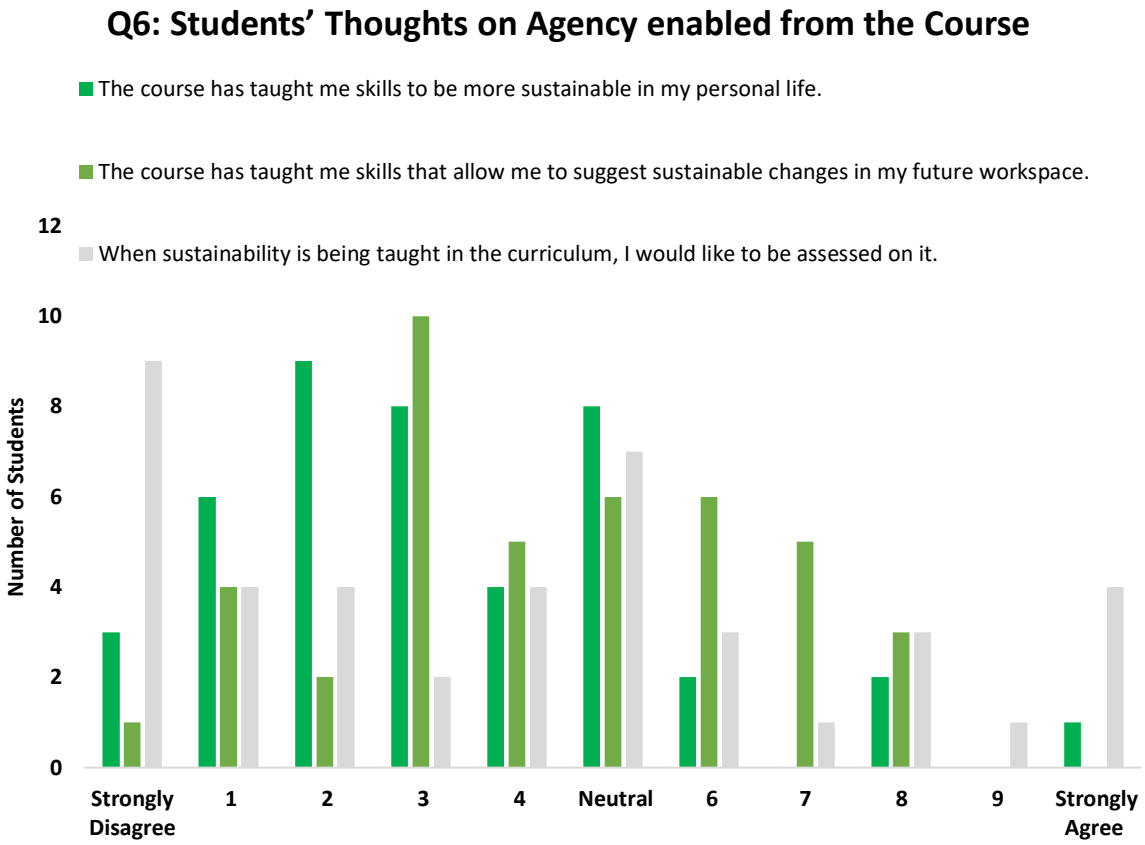
This question highlights the breadth of student opinions on different topics they would like to learn more about when it comes to sustainability. Indeed, there is not one singular topic that seems to be the most important one that everyone is interested in. This might be difficult to implement as it would not be possible to please everyone's opinions. There could, however, be some investigation into the current modules and verify where some of these notions can be added further within that. Or another potential solution would be to get in touch with staff and look at their interest and availability.

Some of the student's interest overlap with other departments, for example someone has mentioned carbon capture technologies which is common in chemical engineering. This suggests that possibly collaborating with other departments where possible might allow to bridge this gap.
Others have also mentioned the industry, this is where another type of collaboration, for example with start-ups can come in handy. Another area of collaboration could be with

think tanks/ governmental organisations or even charities, as two students have specifically expressed an interest in policies, and this is a way to address that in the course too.

There are also students who mention ideas around a more holistic understanding of chemistry and its link to sustainability and its relation to issues in the world and how chemists can make a difference. This is something that needs to be addressed more generally within the curriculum, but it could also possibly be that there is a lecture or two that cover this in the earlier years so that this general idea is provided to students from the start of their degree.

### 3) Sense of Agency



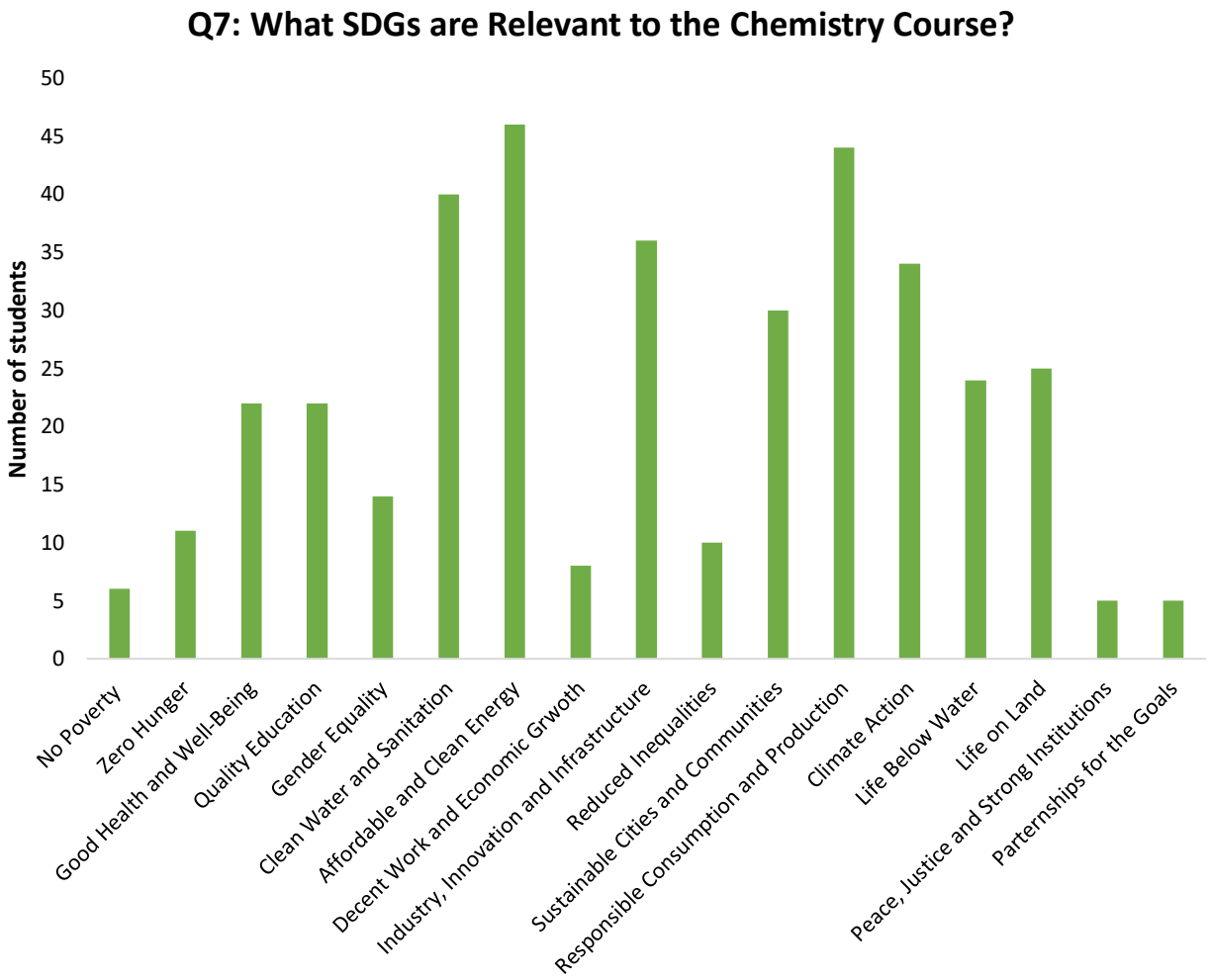

Q6 Summary Histogram

Most/almost all students have not shown any strong agreements to feeling that the course has taught them skills with regards to being more sustainable (88%) or taught them skills to suggest sustainable changes in the workplace (67%).

For the first point, it might be interesting to investigate whether that links to the fact that most students reported not engaging actively in ways to mitigate the climate crisis, and would they indeed do that more if they would be taught about it as part of the curriculum. It might be argued that since it is a personal aspect of a student's life, university might not be the place to be learning about these things.
When it comes to the workplace however, it is somewhat concerning that 67% of students who answered this question do not feel equipped to make any sustainable suggestions in their future careers. This is especially worrisome as there does not seem to be a difference

of opinion between students closer to graduating compared to students earlier in their degree. Since the department is training the future chemists and it has already been mentioned how important and urgent the climate crisis is, this is definitely a gap that would need to be addressed in the curriculum.

In terms of assessment, a good number of students (40%) strongly oppose the idea of being marked on the sustainability content being taught whereas a select few would strongly agree to that statement. It might have been useful to ask students questions more generally about assessment, as it may only be students' opinions in general and not specific to the topic of sustainability. However, this still emphasises that when planning the assessments, it would be important to try and have mixed format, combining formative and summative to maximise overall student satisfaction.




Q7 Summary Histogram

It is unsurprising that SDGs revolving around peace and justice, poverty and economics are the least selected when asked if it is related to the chemistry course.
It is a little bit interesting however, that the "vote" for them is not 0, implying that some students still see the relevance of chemistry in these goals, despite it being not so evident.

This could also be content to add in topics of i-Engage as opposed to the pure chemistry modules.

On the other hand, it is also expected that students choose the SDGs in relation to energy, water and consumption/production and industry and climate action as they are very obviously related to chemistry. This would be good to include in specific chemistry modules, even if not done explicitly.

Perhaps, not as many students chose the Good Health and Well-Being SDG as one would assume given that chemistry topics also includes medicinal chemistry and chemical biology, and surprisingly it is selected as many times as Quality Education. This might indicate a lack of understanding of the big picture, where students are not making the links between the SDG about Good Health with the content of chemistry that is directly related such as within modules that teach medicinal chemistry. Or maybe might indicate that not as many students taking those modules have answered this survey.

It might be good to look into specifics of other research that has been done to show the links between SDGs and chemistry and to make a resource for students that want to know more/or for related modules.

**Q8: In which existing modules do you think these SDGs could be implemented in? Do you see any evidence of this?**

| | MM | Practical Chem | Organic Chem | Sustainable Chem | Other specific Modules | SDGs are distracting | Total |
|---|---|---|---|---|---|---|---|
| **Total Frequency** | 7 | 7 | 5 | 2 | 8 | 2 | 31 |

The students' answers from this question helps identify certain themes of where certain modules have been largely more linked to sustainability than others.

Many students mentioned the 2nd year Macromolecules and Materials (MM)[7] as a module where they have learnt about sustainability/ SDGs. This is likely as one of the lectures from the materials part of the module did include them in one of their slides. Mostly students did not elaborate only one mentioned the lecturer having done an "excellent job". It would be useful to look into the content of this module further and to see if it is truly mentioning sustainability enough and how could we implement the good aspects of this module in other possibly equally relevant modules.

Practical Chemistry was also mentioned by a lot of students. There has not been much specificity. However, a little bit more details than for MM. Two students highlighted the

[7] This module focuses on Materials, Polymers and Biopolymers.

sustainable practices in labs, and another student mentioned the hack-it lab directly. That was a 1st year group project lab in collaboration with a start-up Noptla (that makes plastic-free packaging using seaweed). Students had to come with a new seaweed-based product[8]. The sustainability within the Hack-it lab could be investigated further, and we could see if any of those elements can be implemented in other labs in different years. As for the lab practices, perhaps they could be highlighted more clearly to all students so that they have no doubts about it.

Some students have expressed the thought of wanting more to be included in the organic chemistry courses about green reactions and more sustainable ways of synthesis.
One person has said *"For example, organic synthesis modules could incorporate 'Responsible consumption and production' by discussing the impact of scaling up reactions".* While another student has written *"Organic chemistry modules should discuss more ways to make synthesis greener, for example solvent selection and while sustainability is mentioned occasionally in organic chemistry modules it is only very minimal".*
Possibly because organic chemistry tends to involve reactions that need a lot of energy and high temperatures, so they must have thought that there should be more linked to how to make those synthetic routes more sustainable. This is clearly defining a gap in the curriculum which could be addressed. It is important to understand this more in depth specially from the organic chemistry teaching staff.

Few students mention the 4th year Sustainable Chemistry module. Low numbers could be due to the "demographic" of the students taking the survey, not all of them have reached 4th year or are even on 4-year course. Indeed, one of the students mentioned the drawback of this course is being an optional 4th year module and the fact that more should be implemented earlier in the course. This raises a valid point of where should a module be placed, and if it would be more beneficial to have sustainable chemistry modules in the first years of the degree.

Some students were the only ones to mention a specific module. The variety or lack of uniform answers is similar to what was seen in the previous question (Q4) and again raises the issue that students are not always taking away the same content from the same lectures. This may not necessarily be an issue but when it comes to wanting to highlight sustainability it might be useful to investigate this further through for example the intended learning outcomes of the modules. A more concrete way to overcome this would be by having lecturers be more explicit when they are teaching the content and make the links for the students, that way more people would come out of a lecture being able to have grasped that.

However, there are also two students who answered this question by suggesting that they do not think (at least so far in their degree) it is beneficial to cover the SDGs in their chemistry course. Indeed, one of them has said *"None in first year I feel, I don't see how SDGs can be applied to learning fundamental university chemistry"* and the other student mentioned *"Personally, I am not sure at this level (year 2) that it is useful to talk about*

[8] This was the format of this lab when I took it in 2020 (during Covid), but it has since then changed and possibly may not be linked to the start-up anymore.

*environmental applications of chemistry, as the basic knowledge is being acquired"*. They are not expressing the feeling of this being a distraction to the same extent, as the second-year student might be suggesting that the applications of chemistry should only be taught in later years as opposed to within the core content (year 1 and 2). However, the first-year student does not see an importance to addressing the SDGs to learn chemistry. It is interesting, that there are no similar comments from students in later years and that these students felt the need to mention the year they are in when answering this. It could be suggesting that they are aware their thoughts might change. This is of course inconclusive as two students is too small of a data set to be certain, but one could suggest that a student's year might affect their opinions. This would be important to think about and be considerate of when making changes to the curriculum.

Finally, this was a two-part question, asking students what modules could implement SDGs in the first part, and if there is any evidence of that in the second part. Most people did not answer the second part directly. Some do so indirectly by mentioning where they see missing information or where they see that this has been already mentioned. Where students have not said anything, it is not possible to analyse but generally implies that the module probably has potential to address the SDGs whether it was highly implemented already or not.

**Q9: Can you suggest any curriculum activities to introduce to the course that would make you feel like you are making a difference?**

| | Practical Chem Activities | Specific Assignments/ modules | More General practices | Topics/Activities of interest | Uninterested | Total |
|---|---|---|---|---|---|---|
| **Total Frequency** | 5 | 4 | 5 | 6 | 1 | 21 |

Students have highlighted many times throughout this survey, the importance of practical chemistry in the world of sustainability. In this question in particular, students are suggesting activities that can be run in the labs. Most of the comments are generic and not strongly opinionated about what the activity is but rather that there needs to be one. One of the specific comments was it needs to be more like Hack-it and another one was it could be linked to the module/lecture content[9]. Finally, a student has also mentioned the lab practices themselves. These are all useful recommendations that should be taken into consideration whenever the department would get a chance to make changes to the lab experiments.

In terms of assignments, a few suggestions were made as well. One of them was about a specific case study on an SDG (economic growth) while another was suggesting to "*Have at least one assignment that let us understand how urgent this current situation regarding climate change is."* Someone recommended literature reviews and presentations which could be another useful form of assessment on this topic. The common theme is that these

[9] At the moment in the Chemistry Department, lecture modules are separate to practical chemistry.

are more reflective assessments and require critical skills and analysis as well as linking it to the issues of the world today, these are definitely points that would have to be investigated further whenever lecturers will be reviewing changes to assessment.

In terms of more general practices/teaching, students have not only mentioned labs but also lecture modules. Two students have suggested a new core module (year 1 or year 2), although some students have felt that it would be more suited as a third-year optional module, which raises the same question that we have seen come up previously, about different opinions at different degree stages. Someone has suggested *"general sustainability in daily life and responsible practices can be promoted through the i-Engage modules"*. As this is a module that usually teaches topic that are not only chemistry related, so it would be a sensible place to introduce the topic. One other student has suggested turning off heating, which may not be linked to teaching, but shows that there are issues outside the content taught that are coming up to student's minds when thinking about this.

Some students have given more detailed or specific topics of interest that they would like to explore. Again, within the i-Engage module, a student has suggested including more content in relation to consent and sexual harassment. This may not be directly linked to chemistry but given the question about sustainable development goals, this might be where their line of thinking has come from.
One student has suggested visiting a plastic recycling site. It would be worth the department having that sort of field trips or similar for students that might have specific interests.
A student recommended to add the study of sustainability and implementation of it in countries of the global south too, with them being from there, as the current curriculum focuses mostly on developed countries, they have said *"Learning more about how green chemistry can be implemented in the global south, where I am from. The current curriculum focuses heavily on developed nations but the methods are not usually available to less developed countries."* This highlights the fact that the education has not been global enough and does not cover solutions that would be relevant for all students, especially international students with a proportion of them possibly also being from developing countries.
Another comment was about working on start-ups to promote sustainability initiatives. This has been highlighted in question 5 as well, showing the importance of possible collaborations with industry and start-ups.
There is a student who mentioned specifically wanting to look into hands on pollution treatment. This could be an activity that they do as part of a lab or another trip such as visiting the recycling site. Finally, another undergraduate has mentioned *"maybe extra classes on consumerism (!!!), economics, agriculture or ecology".*
This also does not necessarily align explicitly with chemistry; however, it might be a set of general skills they believe students need to have mastered and therefore this might go under the i-Engage module if it is to be implemented.

All the previous comments have shown a lot of enthusiasm from students about topics that they find important and interesting and of course it would be impossible to implement all the changes that they have mentioned, it is not however unlikely that change can still be made more generally based of it. There could also be for example a general assignment that students pick any topic of their choice, whether it is directly related to chemistry such as the plastic recycling or not such as consumerism and write a reflective piece on it and how it

links to their course. Also, while i-Engage was mentioned as a possible place to introduce all these topics, it is a pass or fail module, which already is quite packed, therefore as some students mentioned, a completely new module might be more convenient, or building on existing modules such as was highlighted in question 8.

It is worthy to note that only one student has said that *"I don't think the purpose of the uni curriculum is to make me feel like I'm making a difference."* It could be implied that perhaps other students that said nothing/ did not reply to this question might feel similarly, more likely though, they may simply not have any specific recommendations or thoughts, specially as they have likely not answered other free text questions too.

## Conclusion and Future Work

This student survey has allowed the collection of data on a topic that had not been researched before within the Chemistry Department at Imperial. Indeed, there was previously no information on the undergraduate's opinions about the climate crisis and sustainability in general and none on their thoughts about the curriculum's implementation of those topics. Now from this survey, it is clear that students do see the importance in having more content in their degree related to this, with some exceptions.

In terms of lecture modules, there are specific ones that have been mentioned where these changes could be made, notably organic chemistry modules are lacking content on more sustainable synthetic routes. The Macromolecules and Materials seem to be a lecture course that many students take away sustainable chemistry topics from. This is likely because it is explicitly mentioned, whereas other modules do not make those connections, leaving many students with different opinions about them.
The i-Engage module could be a potentially sensible place to introduce these topics, but it is already quite busy, and it is also pass/fail, so an alternative should be investigated. This could be by introducing more topics to the existing modules, or by introducing a completely new one.
It is important to consider at what stage of the student's degree this addition of new content would have to be, and whether it should be core content that everyone learns or optional content, since few students have not shown much interest in this.

As for practical chemistry, it was addressed several times throughout the survey as an important factor of discussing sustainability through lab practices, as well as participating in laboratory experiments that contribute to solving sustainability issues. Indeed, it would be useful to have clearer communications about what would be the more effective and sustainable way for students to complete their experiments. It would also be an ideal space in the curriculum to include more activities that are directly linked to the topic, such as the Hack-It lab and the green chemistry assignment in 1$^{st}$ year. These two could act as an inspiration for labs in other years as well.

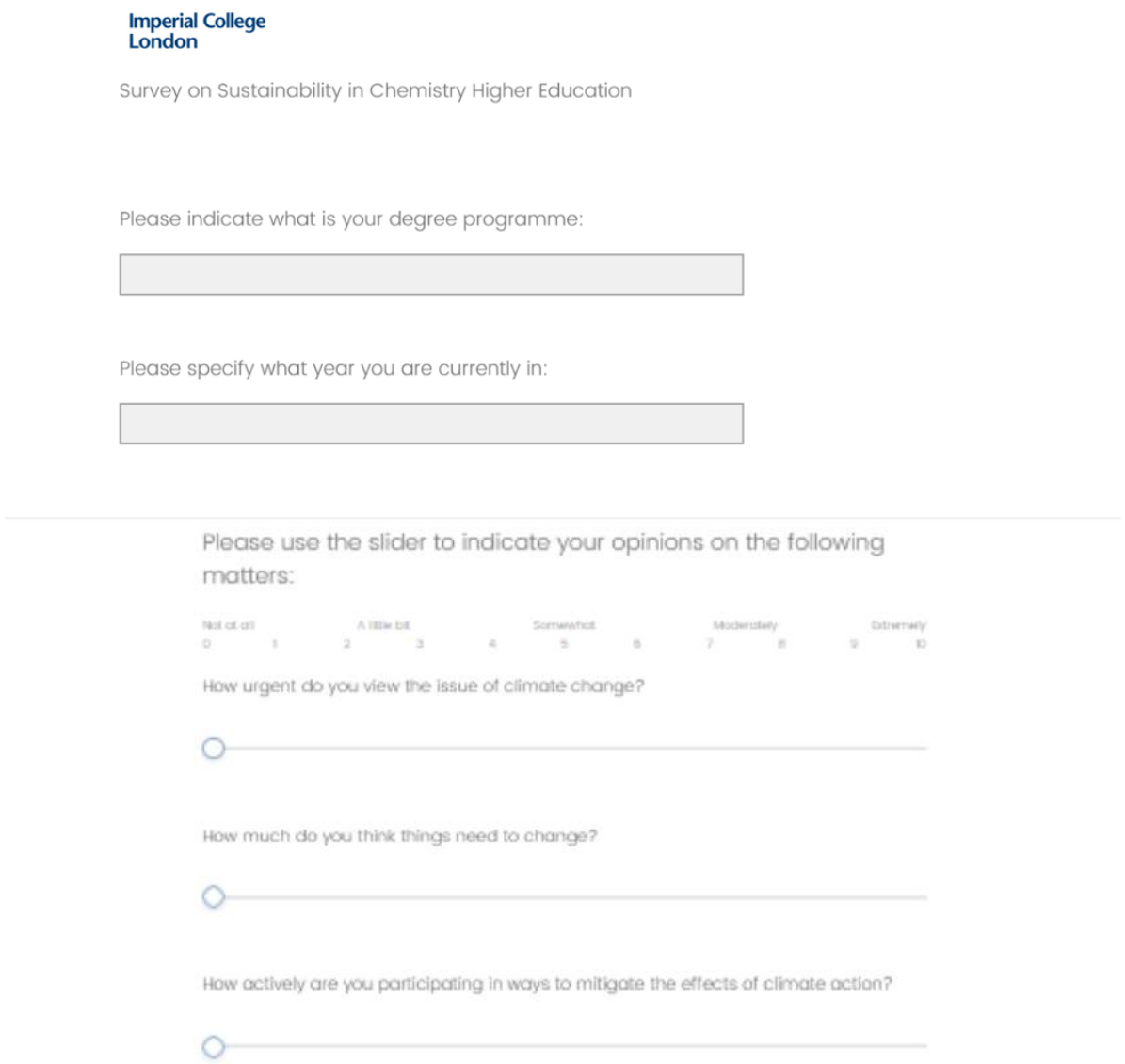
When it comes to assessments, a mixture of pass/fail and summative would make sure that the majority of students could be satisfied. Another key aspect to consider, is that based on many student's ideas for new activities, it would be useful to have more reflective types of coursework or non-exam type of assessments.

Another new feature that might be interesting to implement in the curriculum is that of collaborations. Whether it is with other departments, or start-ups and businesses, as well as NGOs, scientific societies or policy makers, it would be beneficial to bring in all different perspectives since addressing the SDGs does involve more than just chemistry on its own.

This survey has prompted staff interviews which were insightful and brought up new perspectives, from the staff side of the gap. As mentioned it is not possible to share those results externally, therefore a staff survey is currently underway to hopefully gather similar data on a larger scale. Indeed, understanding the reasons for all the gaps that have been brought up in terms of lectures, labs, and assessment from the academic staff perspective would allow for us to have the complete picture and to start implementing changes into the department.

# Appendix

## Student Survey Questions



Imperial College London

Survey on Sustainability in Chemistry Higher Education

Please indicate what is your degree programme:

Please specify what year you are currently in:

Please use the slider to indicate your opinions on the following matters:

Not at all A little bit Somewhat Moderately Extremely

0 1 2 3 4 5 6 7 8 9 10

How urgent do you view the issue of climate change?

How much do you think things need to change?

How actively are you participating in ways to mitigate the effects of climate action?

How would you rank the responsibilities of the following to act on the climate crisis: government, industry, individuals (such as yourself), scientific societies (e.g. Royal Society of Chemistry (RSC)), schools, universities and NGOs (non-governmental organisations)? (1 being most responsible and 7 least responsible)

Drag and drop to reorder:

- Government
- Industry
- Individuals (such as yourself)
- Scientific Societies (such as the Royal Society of Chemistry)
- Schools
- Universities
- NGOs (Non-Governmental Organisations)

Please indicate how much you agree to the following statements:

| Strongly Disagree | | Somewhat disagree | | Neither agree nor disagree | | | Somewhat agree | | Strongly agree | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

I think it is important to include sustainability and climate change directly into the chemistry undergraduate curriculum.

I am satisfied with how much is currently taught about sustainability in my course.

I find that there has been a lot of content related to sustainability in my course so far.

Please describe examples of where you have encountered content that you consider to be teaching you about sustainability. (Consider lectures, labs, workshops, tutorials etc...)

Are there any specific topics in sustainable chemistry that you are interested in knowing more about?

How much do you agree with the following statements:

Strongly Disagree 0 1 | Somewhat disagree 2 3 | Neither agree nor disagree 4 5 6 | Somewhat agree 7 8 | Strongly agree 9 10

I feel like the course has taught me skills with regards to being more sustainable that I can use to make a difference in my personal life.

The course has taught me skills that allow me to suggest sustainable changes in future workplace.

When sustainability is being taught in the curriculum, I would like to be assessed on it.

Please select which of the following 17 Sustainable Development Goals (SDGs; https://sdgs.un.org/goals) you think are most relevant to the chemistry course:

- ☐ No Poverty
- ☐ Zero Hunger
- ☐ Good Health and Well-Being
- ☐ Quality Education
- ☐ Gender Equality
- ☐ Clean Water and Sanitation
- ☐ Affordable and Clean Energy
- ☐ Decent Work and Economic Growth
- ☐ Industry, Innovation and Infrastructure
- ☐ Reduced Inequalities
- ☐ Sustainable Cities and Communities
- ☐ Responsible Consumption and Production
- ☐ Climate Action
- ☐ Life below Water
- ☐ Life on Land
- ☐ Peace, Justice and Strong Institutions
- ☐ Partnerships for the Goals

In which existing modules do you think these SDGs could be implemented in? Do you see any evidence of this?

Can you suggest any curriculum activities to introduce to the course that would make you feel like you are making a difference?

## Student Survey Answers to Free Text Questions

### Examples where people have encountered Sustainability in the course so far: (Q4)

Students answers in terms of labs:

| Answer | Number of Students |
|---|---|
| Green chem assignment in 1st year | 12 |
| Hack-it | 5 |
| Emerging Tech | 1 |
| Labs in general | 7 |
| Nickel catalyst lab | 1 |
| Y2 synthesis proposal | 1 |

Student answers in terms of the rest of teaching:

| Answer | Number of Students |
|---|---|
| Macromolecules and Materials was mentioned the most | 3 |
| Specific staff member was mentioned by name for having mentioned sustainability | 3 |
| Solvents module was mentioned | 2 |
| Sustainability module of 4th year | 5 |
| Lectures on renewable energy (4th year courses) | 2 |
| Lectures on “the industry perspective” | 1 |
| Mentioned in photochemistry lectures of ESB | 1 |
| Comments on organic chem | 2 |
| Comments on catalysis | 1 |
| Processable electronics 4th year module | 1 |

**Topics Students Want to Learn More About (Q5)**

Answers:

1. Green solvents and green synthetic chemistry
2. Renewable energy (I am aware that there is a 4th year lecture course about this)
3. Plastic recycling and refinement processes
4. Downsides of manufacture of materials considered sustainable (eg water needed to produce cotton bags)
5. I would like to know more about the costing and the process of ordering chemicals, equipment etc.
6. Governmental policies
7. Broadly, a more in depth look at the issues and how we as chemists can solve the issue. I think a whole module in first year is warranted based on how important the issue is.
8. Plastic
9. More environmentally friendly catalytic solutions to heavy metal etc catalysts
10. I'd like to know a lot of various applications in all the different parts of chemical science
11. Maybe summarise all the current sustainability issues and make it clear what the actual different problems are.
12. Creating clean feed stocks for industrial processes
13. Waste water treatment, carbon capture technologies
14. Interested in knowing more about policies
15. I am very interested in the materials of the equipment used in lab
16. Life cycle analysis, if it is possible to make how to make lab environments (which are incredibly wasteful) more sustainable and how
17. I'd be interested in learning about better ways to make reactions more environmentally friendly
18. Toxic gas treatment, food safety
19. New research that enhances sustainability, such as organocatalysis and in-water reactions
20. Geochemistry; Specifically what can we as chemists do to further improve sustainability
21. Sustainable energy
22. Carbon capture technology and its development, and development in sustainable materials.

| | **Lab related** | **Industry Related** | **Related to existing modules** | **More Holistic** | **Specific Techniques** | **Other Specifics** |
|---|---|---|---|---|---|---|
| **Number of Answer** | 5,15,16,17 | 4,5,12 | 1,2,9,17 | 7,10,11,20,21 | 3&8, 13&22, 16,18,19 | 6&14,20 |
| **Total Frequency** | 4 | 3 | 4 | 5 | 7 | 3 |

**In which existing modules do you think these SDGs could be implemented in? Do you see any evidence of this? (Q8)**

1. i-Engage. No evidence especially gender equality when misogyny, sexual assault and sex offenders are running rampant in the department
2. Lectures and maybe external speaker workshops
3. Life on Land &industry innovation (MM year 2, applications of different materials), clean water (practical chemistry, like the Hack It lab about removing pollutants)
4. Mostly in the Practical Chemistry modules across all years. I see evidence in the way labs are run, where we are encouraged to be mindful with how much material we use. Also in the assignments mentioned in an earlier question.
5. I think a lot of professors do research on solar cells and direct air capture. These could definitely be incorporated to a greater extent say into the macromolecules course.
6. Macromolecules and materials…
7. Chemistry of molecular systems covers catalytic cycles but from the perspective of metallic catalysts that can introduce polluting byproducts at the end of their life cycles. It would be beneficial to learn about other types of catalysts that are perhaps more sustainable
8. Macromolecules and Materials, yes. Practical Chemistry 2, yes.
9. Y4 Sustainable chemistry course covers these SDGs however as its an optional module not all students take this and it could we worth implementing into earlier years too. For example, organic synthesis modules could incorporate 'Responsible consumption and production' by discussing the impact of scaling up reactions (this is covered a bit in the Y3 Process Chemistry course but again its an optional module)
10. The biggest place where we are already starting to see this would be "Practical Chemistry" ie the labs. In the lecture courses, improvements can be made for example talking about sustainability of organic syntheses in "Control and Selectivity in Molecular Synthesis" and the role catalysts play in sustainability in "Chemistry of Molecular Systems" or , the role of electrochemical reactions in improving sustainability in "Solids, Liquids and Interfaces". Prof X however did an excellent job of specifically mentioning the SDGs in their part of the lecture course "Macromolecules and Materials"
11. None I first year I feel, I don’t see how SDGs can be applied to learning fundamental university chemistry
12. Maybe introduce a third year optional course on it?
13. Practical chemistry;
14. Practical Labs - either with more sustainable practices or working with chemicals that directly matter to/promote sustainability
15. They could be implemented into all modules to some extent. I dont think in the first year there has been a lot of evidence of this.
16. Organic chem modules
17. Some applications based modules: Chemistry of the Elements; Electronic States and Bonding; Analysis of Molecules, Materials and Mixtures; Chemistry of Molecular Systems; Macromolecules and Materials. Third year modules: Electronic Properties of Solids; Adv. Transition Metals; Lathanides and Actinides; Materials Chemistry; Solvents
18. Practical chemistry module, yes but very few
19. COTE - already being implemented, where applications to sustainbility are talked about. Organic chem - where green reactions can be highlighted
20. I think they are implemented into a lot of the 3rd year modules., such as Lanthanides and Actinides, ATMC, Functional Inorganic materials. Also in Practical Chemistry, especially in year 1 Hack It
21. During workshops

22. I think they can be integrated in most modules or even create an entirely new module (which must be part of the first two years; ie the core years)
23. Organic chemistry modules should discuss more ways to make synthesis greener, for example solvent selection and while sustainability is mentioned occasionally in organic chemistry modules it is only very minimal
24. iExplore, Material and Macromolecules
25. Materials chemistry, practical chemistry, sustainable chemistry, functional inorganic materials
26. Personally, I am not sure at this level (year 2) that it is useful to talk about environmental applications of chemistry, as the basic knowledge is being acquired

| | **MM** | **Practical Chem** | **Organic Chem** | **Sustainable Chem** | **Other specific Modules** | **Finds this distracting** |
|---|---|---|---|---|---|---|
| **Number of Questions** | 3,5,6,8,10, 17,24 | 4,8,13,14,18,20,25 | 9,10,16,19,23 | 9,25 | 1,7,9,10,17,19, 20,25 | 11,26 |
| **Total Frequency** | 7 | 7 | 5 | 2 | 8 | 2 |

**Suggestions to curriculum activities (Q9):**

1. Consent, harrassment and sex offence courses in i-Engage modules
2. Would be interesting to visit plastic recycling sites
3. I don't think the purpose of the uni curriculum is to make me feel like I'm making a difference.
4. Maybe an activity looking at the SDG Decent Work and Economic Growth, such as a short essay where you have to discuss a successful case study of this.
5. Make students aware of disposable lab items and make available reusable items
6. I think a first or second year module on green chemistry would be great. An activity could be an undergraduate lab (unsure of details).
7. Have at least one assignment that let us understand how urgent this current situation regarding climate change is.
8. Some lab time could be dedicated to hands on practicals about green chemistry-- learning about itnfrom a practical standpoint could inspire students in upcoming cohorts to dedicate research time to it if they so chose.
9. Learning more about how green chemistry can be implemented in the global south, where I am from. The current curriculum focuses heavily on developed nations but the methods are not usually available to less developed countries.
10. As I mentioned above I have given a few examples where it can be demonstrated how sustainability can be, and is, considered in the core concepts discussed in the lecture courses. However at the same time general sustainability in daily life and responsible practices can be promoted through the i-Engage modules.
11. More labs like Hack It
12. More modules like emerging technology to teach us about how green chemistry is used in practise
13. Working on start-ups to see and promote sustainability initiatives
14. Learning more about the topic
15. Maybe setting up labs/practical coursework directly related to a sustainble application covered in the lecture course
16. Hands on pollution treatment
17. Literature reviews, Presentation, Innovative ideas.

18. Turning off the heating, maybe extra classes on consumerism (!!!), economics, agriculture or ecology

| | Practical Chem Activities | Specific Assignments/ modules | More General practices | Topics/Activities of interest | Other |
|---|---|---|---|---|---|
| **Number of Answer** | 5,6,8,11,15 | 4,7,12,17 | 5,6,10,14,18 | 1,2,9,13,16,18 | 3 |
| **Total Frequency** | 5 | 4 | 5 | 6 | 1 |

**Staff Interview Questions**[10]

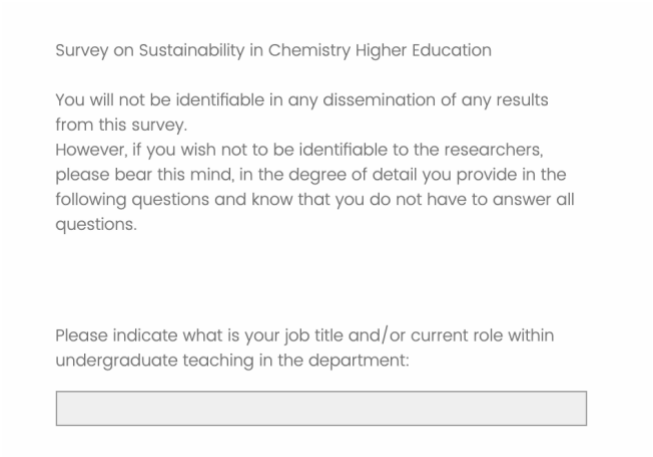
1. On a scale from 0 to 10: how urgent do you view the climate crisis? (0 being not at all and 10 being extremely)
2. On a scale from 0 to 10: how much do you think needs to change?
3. On a scale from 0 to 10: how satisfied are you with the department's current inclusion of sustainable principles in teaching and in practices?
4. How sustainable do you feel the lab practices that are put in place are?
5. Are there any downsides or barriers to making the lab activities more sustainable?
   a. If so, what are they and could they be overcome?
   b. Have you tried doing this in the past?
6. Can there be more transparency about the protocol/system followed to ensure sustainability?
   a. -prompt: Is it obvious to incoming students that these are the intentions?
   b. A few students mentioned the restrictions on certain material in the lab as sustainable but were unsure if that was the rationale behind it, perhaps it could be emphasized more?
7. Do you have any thoughts on changing lab assessments to include more sustainable chemistry?
8. What do you think new lab activities that promote sustainability could look like?
9. Some students have mentioned the idea of a new sustainability module. What are your thoughts on this?
   9.1 What year should it be in?
10. Do you think there should be an explicit component to the chemistry curriculum ILO "Demonstrate intellectual and personal development as a university learner and citizen to enable purposeful and responsible engagement with the world" about sustainability and having students graduate as "change makers"/ able to tackle the challenges we face in today's world?
11. Students have mentioned that organic chemistry could include a little bit of contents related to sustainability. To what extent do you agree with that?
    11.1 Prompt: Or would it be getting in the way of the teaching/too difficult of a change? -similar wording to downsides and barriers.
    11.2 Have you tried doing this in the past ?
12. What are your thoughts about implementing more sustainable practices and teaching in the department?

[10] Not all questions were asked to all staff, it depended on their role and expertise.

12.1 What lecture content do you believe needs to be added?
12.2 What about workshop and tutorial activities?
12.3 Do you think there needs to be a component in assessment to it?
12.4 And within the practical chem curriculum?
12.5 Do you have any recommended resources?
12.6 Would you want to be involved in changes?
12.7 What barriers do you perceive?
12.8 In your opinion should there be collaboration with industry/other departments/NGOs etc?

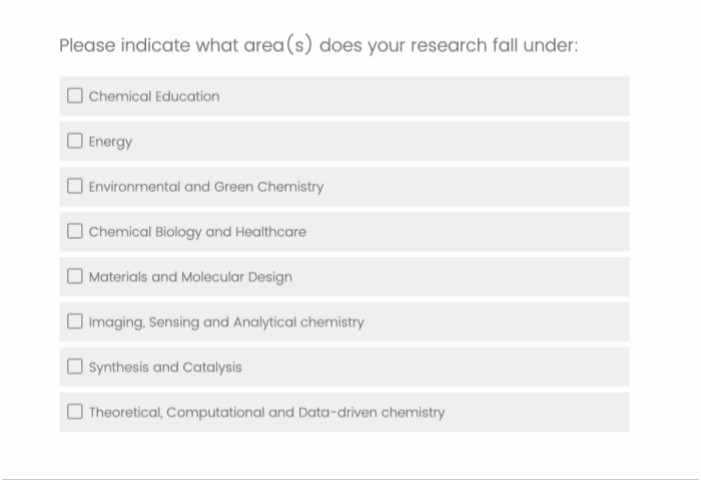
13. As it is a teaching activity where you have a bit more freedom, do you emphasize the topics of sustainability in your tutorials?
14. Are you satisfied with the way the module you teach it is currently run?
    14.1 question about assessment can be prompted-
    14.2 And with the way it's positioned in the curriculum (as 4th year module)?

**Staff Survey**[11]


Survey on Sustainability in Chemistry Higher Education

You will not be identifiable in any dissemination of any results from this survey.
However, if you wish not to be identifiable to the researchers, please bear this mind, in the degree of detail you provide in the following questions and know that you do not have to answer all questions.

Please indicate what is your job title and/or current role within undergraduate teaching in the department:


Please indicate what area(s) does your research fall under:

- Chemical Education
- Energy
- Environmental and Green Chemistry
- Chemical Biology and Healthcare
- Materials and Molecular Design
- Imaging, Sensing and Analytical chemistry
- Synthesis and Catalysis
- Theoretical, Computational and Data-driven chemistry

[11] This survey is still open and therefore no answers have been shared in this report.

Please indicate your teaching section:

- ○ Inorganic
- ○ Organic
- ○ Physical

Please indicate how long you have been involved in teaching activities in the department:

→

Please use the slider to indicate your opinions on the following matters:

Not at all 0 | 1 | A little bit 2 | 3 | 4 | Somewhat 5 | 6 | Moderately 7 | 8 | 9 | Extremely 10

How urgent do you view the issue of climate change?

How much do you think things need to change?

How actively are you participating in ways to mitigate the effects of climate change in your personal life?

How actively are you participating in ways to mitigate the effects of climate change in your professional life?

How would you rank the responsibilities of the following to act on the climate crisis: government, industry, individuals (such as yourself), scientific societies (e.g. Royal Society of Chemistry (RSC)), schools, universities and NGOs (non-governmental organisations)? (1 being most responsible and 7 least responsible)

Drag and drop to reorder:

- Government
- Industry
- Individuals (such as yourself)
- Scientific Societies (such as the Royal Society of Chemistry)
- Schools
- Universities
- NGOs (Non-Governmental Organisations)

Please select which of the following 17 Sustainable Development Goals (SDGs; https://sdgs.un.org/goals) you think are most relevant to the chemistry undergraduate course:

- [ ] No Poverty
- [ ] Reduced Inequalities
- [ ] Zero Hunger
- [ ] Sustainable Cities and Communities
- [ ] Good Health and Well-Being
- [ ] Responsible Consumption and Production
- [ ] Quality Education
- [ ] Climate Action
- [ ] Gender Equality
- [ ] Life below Water
- [ ] Clean Water and Sanitation
- [ ] Life on Land
- [ ] Affordable and Clean Energy
- [ ] Peace, Justice and Strong Institutions
- [ ] Decent Work and Economic Growth
- [ ] Partnerships for the Goals
- [ ] Industry, Innovation and Infrastructure

→

Please use the slider to indicate how much you agree with the following statements:

Strongly disagree 0 1 | Somewhat disagree 2 3 | Neither agree nor disagree 4 5 6 | Somewhat agree 7 8 | Strongly agree 9 10

I think it is important to include sustainability and climate change explicitly into the chemistry undergraduate curriculum. ☐ I don't know

I am satisfied with how much is currently taught about sustainability in the curriculum. ☐ I don't know

I find that there is a lot of content related to sustainability in the course. ☐ I don't know

In your opinion how should sustainable chemistry be taught?

- [ ] As part of a standalone module in core content (year 1 or 2)
- [ ] As part of a standalone module in optional content (year 3 and/or 4)
- [ ] As part of ancillary modules (year 1 and 2)
- [ ] As an insertion into existing modules
- [ ] As part of practical chemistry (labs)
- [ ] Other, please specifiy:

What do you perceive as being the biggest barrier(s) to the department to include more sustainability into the curriculum?

- [ ] Limited time in students timetables
- [ ] Limited staff time for making changes
- [ ] Resistance from staff
- [ ] Resistance/disinterest from students
- [ ] Lack of knowledge on the topic
- [ ] Lack of motivation
- [ ] Lack of dedicated staff
- [ ] Lack of coordination across modules causing over-emphasis/under-emphasis on the topic
- [ ] Worry of it becoming virtue signalling rather than meaningful teaching
- [ ] Other, please specify:

What current sustainable teaching and lab practices are you aware of that are happening within the department?

In your opinion, how can sustainability be further incorporated into our teaching?

In your opinion, what current degree content could be reduced or removed to make space for sustainability content?

→

In general, what skills do you expect students take away from your own teaching?

- [ ] Critical Thinking
- [ ] Holistic Approach and/or Systems Thinking
- [ ] Prioritisation and Decision Making
- [ ] Communication Skills
- [ ] Reflection and/or Self-Reflection
- [ ] Collaboration and Team Work
- [ ] Awareness of Global Issues
- [ ] Independent Research
- [ ] Other, please specify:

How can the context of sustainability be used to develop those skills? (This could be through workshop, tutorial, assessments or other...)

To what extent do you feel like your own teaching has already incorporated sustainability?

- ○ None at all
- ○ A little
- ○ A moderate amount
- ○ A lot
- ○ A great deal

What has enabled you to include sustainability related content in your teaching in the past?

- [ ] Support from research staff
- [ ] Support from GTAs
- [ ] Teaching content where there is scope to include it
- [ ] Collaboration with teaching fellows/learning technologists
- [ ] External collaboration with industry
- [ ] Other, please specify:

What barriers have you faced, and/or do you anticipate?

- [ ] Lack of relevance to content taught
- [ ] Not enough of time in schedule for it
- [ ] Lack of support
- [ ] Resistance to change
- [ ] Lack of motivation
- [ ] Lack of coordination across modules causing over-emphasis/under-emphasis on the topic
- [ ] Disinterest from students
- [ ] Lack of knowledge/resources
- [ ] Difficulties with bureaucracy
- [ ] Distracting students from course content
- [ ] Other, please specify

→