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Using an Inclusive Curriculum Framework to address an awarding gap in a first-year chemistry module.

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GRAPHICAL ABSTRACT

Inclusive Curriculum Framework template tool			
	Create an accessible curriculum	Students see themselves reflected in the curriculum	Equip students to work In a global and diverse environment
In the concept			
In the content			
In the delivery			
In the assessment			
In the feedback			
In the review			

ABSTRACT

Across the United Kingdom Higher Education system, the percentage of white students attaining a first or upper second-class degree exceeds the that of Black Asian Minority Ethnic (BAME) students. This is known as the BAME degree awarding gap. Awarding gaps are also seen at module level. The BAME module awarding gap is defined as the difference in average module mark between white students and BAME students. A large BAME module award gap for a first year environmental and inorganic chemistry module prompted a review of its curriculum. The redevelopment of the curriculum was guided by Kingston

University's Inclusive Curriculum Framework (ICF) tool. Project Based Learning, and on-line support for laboratory techniques and practical coursework assessments were introduced. These changes were made to make the curriculum more accessible and enable students to see themselves within the curriculum. Student feedback was positive, and the BAME module awarding gap was closed.

KEYWORDS
First Year undergraduate/General, Laboratory Instruction, Curriculum, Environmental Chemistry, Collaborative/cooperative learning, Atmospheric Chemistry, Minorities in Chemistry

BACKGROUND

In the United Kingdom the widening the participation of Black Asian and Minority Ethnic (BAME) students in Higher Education has been successful. The percentage of BAME school leavers going to university is greater than that of white school leavers. In the United Kingdom undergraduate degrees are graded according to a classification system with a first-class degree being the highest classification, followed by upper-second class, lower-second class and third class. A good honours degree is defined as either a first or upper-second class honours degree. However, the success of BAME students in Higher Education does not match that of their white counterparts. This is reflected in the well-publicised BAME degree awarding gap, which is the difference between the percentage of white and BAME students getting "good honours degree" .[1]. Within the BAME grouping, Black African/Caribbean students are reported as having the largest degree awarding gap. Nationally in 2018/9 the awarding gap between black students and white students was 22.6 % with 81.4% of white students being award a good degree compared to only 58.8% for Black students.[2] Persistent differential outcomes between student groups based on socio-economic class, age and disability also exist.[3,4] Achievement gaps in first-year chemistry modules have been reported by Harris *et al.*[5], who noted that reducing such module achievement gaps could have significant impact on the aim of realising equity in students completing STEM majors. Spitzer and Aronsen[6] noted that achievement gaps are an international issue and suggested a number of ways to address it, including greater use of cooperative learning.

Kingston University is a post-1992 university in South West London with approximately 17,000 students, over fifty per cent of students at Kingston are from BAME backgrounds and many come from under-represented neighbourhoods. At Kingston University the development of an inclusive curriculum has been an important aspect of addressing differential degree outcomes. The University's Equality, Diversity and Inclusion (EDI) unit created an Inclusive Curriculum Framework (ICF) to inform the University's teaching programmes by embedding equality of opportunity, diversity and inclusion across the curriculum.[7,8] An Inclusive curriculum is one in which content, teaching practices and assessment are "designed and delivered to engage students in learning that is meaningful, and accessible to all".[9] Hocking identified several key themes regarding inclusive curriculum design that include:

- "What knowledge is included in the curriculum, who selects it and why" which is a key aspect of the decolonising the curriculum and science movement.
- The role of Technology Enhanced Learning (TEL) in supporting a diverse range of students
- Curricula that can be customised by student (or co-created with staff) so they can see themselves in the curricula. This can minimise the need for individual adjustments.

A key aim of an inclusive curriculum is to allow differences to coexist in a mutually beneficial way and all students feel that they belong.

AN INCLUSIVE CURRICULUM FRAMEWORK

The Kingston Inclusive Curriculum Framework (ICF) can be applied at module, programme or institutional level. The framework focuses on challenging staff to reflect on the extent to which their practices and content:

- are accessible,
- enable students to see themselves in the curriculum and
- prepare students to contribute positively to a diverse world.

Making practices and content more accessible entails more than just making adjustments, it is mindful of cultural differences and ensures that the curricula do not give specific advantages to students from specific cultural groups. Enabling students to see themselves reflected in the curriculum focuses on the challenges of colonised curricula and the need for ethnic groups to be represented in the content and as role models and teaching staff. The final principle of preparing students to contribute to and work in a diverse, global environment recognises that students who are exposed to multiple perspectives and learn to respect diversity and inclusion at university will be better prepared for the workplace.

The use of the ICF has had some success across the university, with Kingston University's BAME degree awarding gap being reduced from 18.2 percentage points in 2013/14 (78.5% white, 60.3% BAME) to 10.2 percentage points (80.7% white 70.5% BAME) in 2018/9. Considerable progress has been made in closing the BAME degree awarding gap in the Faculty of Science, Engineering and Computing at Kingston University. In 2013/4 75.4% of white students achieved a good degree (first or upper-second class) from the Faculty of Science Engineering and Computing compared to 57% of BAME Students. In 2018/9 the percentage of BAME students being awarded a good degree had risen to 76.4% whilst the percentage of white students awarded a good degree had risen only slightly to 80.5%. This represents a reduction in the Faculty of Science, Engineering and Computing BAME degree awarding gap from 18.4% to 4.1%, as illustrated in Table 1.

Table 1. BAME Degree-Awarding Gap Data for the Faculty of Science, Engineering and Computing

Academic Year	Students Achieving a Good Degree,[a] %		
	White	BAME	Gap
2013–2014	75.4	57.0	18.4
2014–2015	77.8	60.0	17.8
2015–2016	79.8	68.9	10.9
2016–2017	79.9	73.1	6.8
2017–2018	81.4	73.2	8.2
2018–2019	80.5	76.4	4.1

[a] Good Degree is first or upper-second clss .

To help staff to monitor progress, the university provided data on degree awarding gaps at course and School level and module average awarding gaps for individual modules.[10]

In the context of closing award gaps in chemistry a meta-analysis of research on active learning classes In STEM is particularly noteworthy.[11] It indicated that active learning benefits all students, but disproportionately benefits students from under-represented backgrounds. A significant reduction in awarding gaps for exam scores and pass rates was observed for classes with active learning. Freeman has defined Active learning as "engaging students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work".[12]

This paper illustrates how the Kingston ICF was used to redevelop a first chemistry module which was identified as having a large BAME module average awarding gap.

KINGSTON UNIVERSITY INCLUSIVE CURRICULUM FRAMEWORK TEMPLATE TOOL

The Inclusive Curriculum Framework (ICF) builds inclusivity from 'concept to review'. The framework (Table 2) is a tool to help map interventions that can address the principles of the ICF in the concept, content, delivery, assessment, feedback and review of a module.

Application of ICF template Tool to a First Year Inorganic and Environmental Chemistry Module

To further its work on addressing awarding gaps, in 2017/8 Kingston University provided data on BAME module awarding gaps (the difference in average module mark between white students and BAME students) for every module. This data indicated that in 2017/8 BAME students averaged 12.2% less than white students on a first-year Foundation in Inorganic and Environmental Chemistry module. This was the largest award gap of any module within the department of Chemical and Pharmaceutical Sciences at Kingston University. In order to address this gap, the ICF was used as a starting point to see how the module could be made more inclusive.
Two major changes were made to address the three principles of the inclusive curriculum framework

1. A Project Based Learning (PjBL) approach replaced a lecture series in the teaching of atmospheric environmental chemistry
2. Greater support for laboratory work and its assessment was developed.

How these changes were mapped against the principles of ICF and its dimensions from concept to evaluation is illustrated in Table 2.

Table 2. Map of Action to Address Selected Dimensions of Kingston University's Inclusive Curriculum Framework for a First-Year Inorganic and Environmental Chemistry Module

Aspect of the curriculum	The three principles of Kingston University's Inclusive Curriculum Framework		
	Create an Accessible Curriculum	Enable Students to See Themselves Reflected in the Curriculum	Equip Students to Work in a Global and Diverse Environment
In the Concept	Reflecting on awarding gap	Employ PjBL to allow co-creation of curriculum	Teaching methods to develop key employability skills
In the Content	Introduce some co-creation through PjBL	Support co-creation	Transboundary nature and global impact of pollution
In the Delivery	Timetabling; Laptop computer loans	Provide space for students to air their own opinions in PjBL workshops	Development of teamwork
In the Assessment	Seen exam question; Support for on-line lab assessments	Peer assessment of presentations	Communication skills
In the Feedback	Automated marking of lab assessments with immediate feedback	Peer assessment and feedback on oral presentations for PjBL	Student reflection on their teamwork experience
In the Review and Evaluation	Act on student feedback	Course rep lead student evaluation	

PROJECT BASED LEARNING

Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are often used interchangeably as there is a large degree of overlap. One way of distinguishing them is that in PjBL students have to find the necessary information or skills needed to produce an output (object, report or presentation) rather than drawing on existing knowledge. Whereas PBL is normally more focused on producing a solution to an open-ended real-world problem.

PjBL is based on a constructivist approach to learning; the aim of PjBL being the transformation and construction of new knowledge rather than treating students as passive learners who just receive knowledge. The use of PBL and PjBL in chemistry higher education has been reported extensively.[13–17] One of the benefits of PBL and PjBL is their ability to engage and motivate students leading to improved student and staff satisfaction.[18,19] Another key feature of PBL and PjBL is how they help develop transferable/employability skills such as teamwork and communications skills; this is recognised and appreciated by students.[20]

A meta-analysis of twenty years of research on PjBL found a medium to large and positive effect of PjBL on student academic achievement compared with traditional lecturer instruction methods.[21] This analysis is consistent with the finding of Freeman on the benefits of active learning methods towards student achievement.[12]

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In PJBL students usually work in small groups (3-6 students) as this helps motivate them and reduces the chances of some team member not contributing. Feedback from peers and the opportunity to reflect on it helps improve the output of PjBL. Learning to work as a team is key to the success of PjBL so it is important that students have some introduction to teamwork skills and roles to help them work collaboratively before embarking on a project.

Application of Project Based learning in Inorganic and Environmental Chemistry Module

In this module students received a couple of introductory lectures on atmospheric Chemistry and workshop on Belbin team roles, along with some ice-breaker activities before teams were finalised and the projects agreed. The teaching schedule comprised of 8 two-hour workshops across a 12-week semester, a summary of classes is given below. Previously this topic was taught as series of 11 one-hour lectures and 5 one-hour tutorial classes. Students are given advice on the nature and amount of guided independent learning required for the PjBL activities during the workshops and via the Virtual Learning Environment. Approximately 40 hours of guided independent learning were assigned to PjBL.

TW1 Introductory lectures on atmospheric chemistry

TW2 Introduction to teamwork, Belbin roles and icebreaker activities

TW3 Selection of projects and initial planning

TW5 Reporting progress and calculations workshop

TW7 Interim presentations -peer feedback

Action plan for final report

TW9 Drawing conclusions, evaluation of success

TW11 Final presentation and reflection on teamwork

TW12 Work on final reports

This was the students' introduction to teamwork on the chemistry course and they were given the option to form their own teams and choose an atmospheric chemistry pollution problem. The teams were required to collect and analyse data on their chosen atmospheric chemistry pollution problem and produce a summary report. At the beginning of the projects, teams were asked to reflect on what they already knew about the task on what gaps in knowledge and skills needed to be addressed. They then were asked to develop an action plan for the development of their presentations and final report. In consideration of potential digital poverty, workshop rooms were booked each week and lap top loans were available. Teams were required to present progress reports on the collection and analysis of data to the class before producing a final team report. The team report is a piece of formative assessment. The summative assessment is by a seen exam question, based on the assessment criteria of the formative PjBL report. Feedback on the formative PJBL reports highlights any omissions from the report that would be needed to tackle the seen exam question.

Co-creation of curricula in Project Based learning

An attractive aspect of PjBL when considering an inclusive curriculum is that the students effectively co-create the curriculum as they choose the topic and content to be investigated and reported. There are a range of different definitions of co-creation, but they all involve student participation and choice in their learning. In Bovill and Bulley's ladder of student participation in curriculum design the bottom rung is a dictated curriculum with no student interaction.[22] This usually involves the academic creating and delivering the curriculum with no input from students. The fourth rung of the ladder is defined as "wide choice from prescribed limits of the curriculum"; this matches the selection of a topic within the area of atmospheric pollution chemistry.

The PjBL report required an explanation of the science and causes of the problem, a summary of the changes in atmospheric concentration of relevant gases with time using graphs, a reflection on the impact of the problem on global ecosystems, a critical analysis of actions taken or suggested to tackle the problem and an evaluation the success or not of efforts to mitigate the pollution problem. In writing the report the students had free choice on what case studies to draw on or what parts of the globe they focused on.

SUPPORT FOR LABORATORY WORK

Kingston University recruits students from a wide range of non-traditional educational backgrounds including some who have done little practical work before arriving at university. It is well established that pre-laboratory activities are an effective way to prepare students to perform laboratory tasks in a correct manner.[23,24] The provision of pre-laboratory on-line videos has been shown to improve student performance in an introductory general chemistry module.[25] Student-generated video instructions for organic chemistry laboratory techniques were shown to be more effective than in-class teaching assistant instructions.[26] The use of computer simulations to support student practical work in chemistry has been reported but is used less extensively than video clips.[27–30] Virtual reality is beginning to be used to demonstrate laboratory techniques.[31]

Learning Science Ltd Videos and Simulation of Laboratory Techniques.

In order to better prepare first-year students for laboratory work we licensed a suite of the of videos and laboratory simulations developed by Learning Science Ltd.[32] These were integrated into the Canvas Virtual Learning Environment (VLE). Blackburn, Villa Marcos and Williams have previously described the implementation of these resources within a VLE and reported very positive student engagement and feedback.[33] The interactive simulations cover a wide range of laboratory and spectroscopic techniques. In this module simulations on analytical (pipetting, titration, pH meter, preparing standard solutions, accurate weighing) and synthetic techniques (heating under reflux, filtration, recrystallization etc) were used. The attractive feature of theses simulations is that they are very interactive, provide feedback on mistakes made and direct students to further attempts until the correct technique is used, Figure 1.

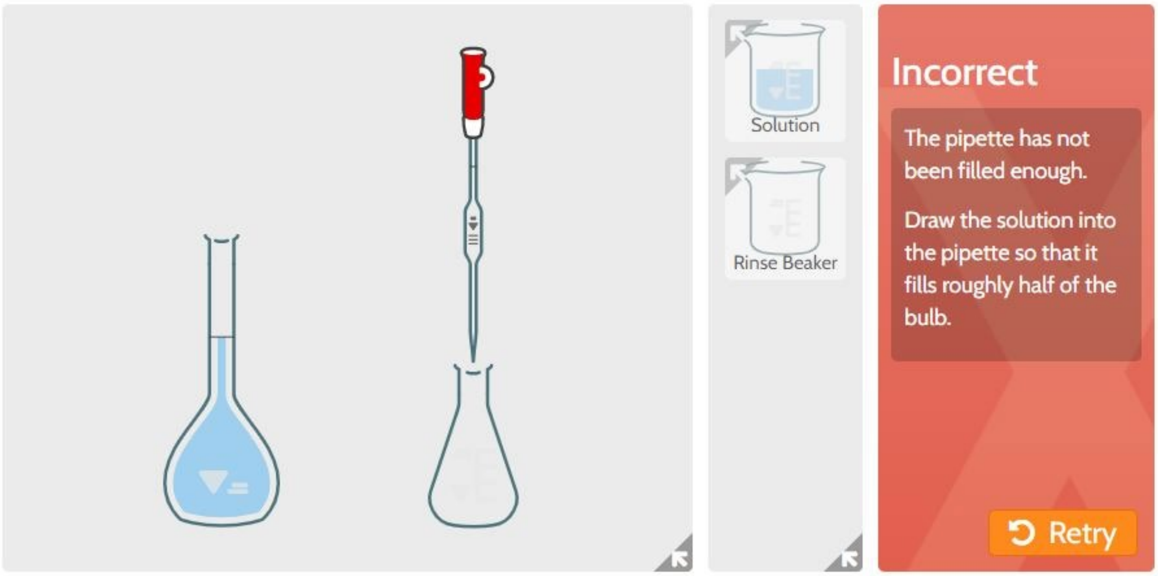

Figure 1. A screen shot of feedback provided to a student after an error in technique when using the laboratory technique simulation hosted by Learning Science Ltd. Reprinted with permission. Copyright 2018

Students were encouraged to use these as pre-lab activities so they could practice techniques before the laboratory classes. Concurrently, we opened a new undergraduate teaching laboratory for chemistry with a dedicated PC for each student, this allowed students to refer to the videos and simulations during the laboratory class. Another issue raised in student feedback was the difficulty of 9 am starts for commuter students. A later start time was introduced to accommodate this request.

Use of Smart Worksheets in Assessment of Laboratory Work.

Smart worksheets are a digital assessment tool developed by Learning Science Ltd. Bespoke lab reports were produced in collaboration with Learning Science Ltd to allow students to enter experimental data and the results of calculations. Support is scaffolded throughout the worksheet in the form of pop-up hints that encourage students to reflect on the validity of their answers before submitting, see Figure 2. The students' results are auto-graded and tailored feedback on the quality of the experimental data is provided. The worksheets employed attempt-based partial grading. Feedback for common and specific errors is provided and students are allowed a second attempt on calculations in order to get a reduced mark if answered correctly at the second attempt. Students can also request the correct answer and forgo a mark. This function allows them to proceed with subsequent calculations.

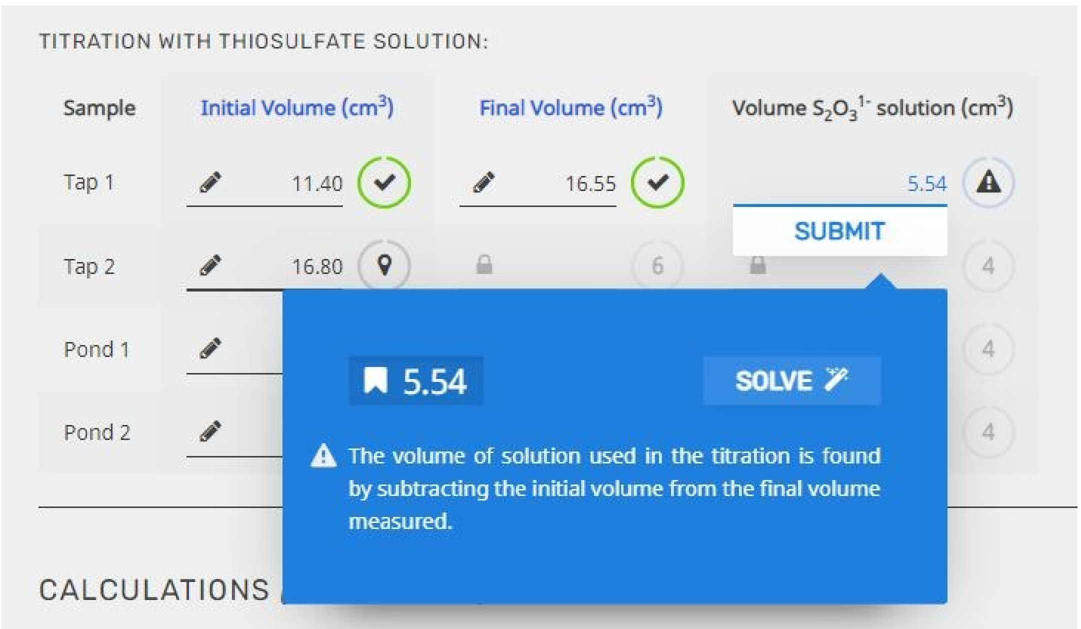

Figure 2. Example of automated feedback provided in laboratory smart worksheet in response to an incorrect answer. Worksheet developed by Learning Science Ltd. Reprinted with permission. Copyright 2018.

IMPACT OF REVISED CURRICULUM

After the introduction of smart worksheets for the assessment of laboratory work, improvements in submission rate and overall average mark for the laboratory report were seen. Table 3 summarises the average marks for the examination and laboratory report portfolio from 2016/17 to 2019/20.

Table 3. Comparison of Average Mark for Module Assessments

Academic Year	Students, *N*	Av. Marks Earned, %	
		Lab Reports	Examination
2016–2017	34	59.2	48.8
2017–2018	30	60.2	51.6
2018–2019	30	67.8	48.2
2019–2020	34	64.0	59.0

The student feedback on laboratory work and Learning Science Ltd resources was very positive

"get to have loads of time in labs, which means I feel more comfortable in them which is great."

Positive comments were also received about the PjBL sessions.

"The pollution topic was very helpful in experiencing group working. and the debates in class were interesting. "

"I enjoyed the fact that my ideas got challenged when shared"

"It was a refreshing change from other parts of the course."

There was also an improvement in the module awarding gap, from -12.2% in 2017/8 to +0.9% in 2018/9. The module awarding gap changed further in 2019/0 with BAME students averaging 10% more than white students. This was possibly influenced by the replacement of on-campus examinations with alternative examination assessments due to COVID-19. These improvements cannot be definitively attributed to the changes made in the module due to cohort variation and the small class sizes (n= 30 to 34).

SUMMARY

An inclusive curriculum framework has been used to guide the review of a first-year inorganic and environmental chemistry module. The review was prompted by the module having a large award gap between white and BAME students. In order to make the curriculum more inclusive, Project based learning and additional support for laboratory work and its assessment were introduced. Laboratory videos, simulations and smart worksheets developed by Learning Science Ltd provided valuable support to students before, during and after the laboratory work. Project based learning provided students with an opportunity to see themselves reflected in the curriculum. These changes helped close the module awarding gap for this module.

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