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| **Academic Year** | AY22/23 | **Semester** | 2 |
| **Course Coordinator** | Roderick Bates | | |
| **Course Code** | CM5092 | | |
| **Course Title** | Chemical Sustainability – An Asian Perspective | | |
| **Pre-requisites** | CM1001 and CM1002 or CM1031 and CM1041 or<br>BS1002 and BS1003 or BS1012 and BS1013 or<br>MS1014 and MS1016 or CB1103 and CH1104 or BG2142<br>or by permission | | |
| **Mutually Exclusive** | none | | |
| **No of AUs** | 3 | | |
| **Contact Hours** | Lectures: 18 hours; Tutorial: 15 hours; presentations: 6 hours | | |
| **Proposal Date** | 23rd May 2022 | | |

**Course Aims**

The primary objective is multicultural. The Singapore economy is highly integrated with the World. Many graduates will find themselves working with colleagues from other countries and/ or cultures because they are employed by multinational companies, whether Singapore owned or not, or posted overseas, or simply have colleagues from overseas. Being able to adapt to work with people from such different backgrounds will be an increasingly important skill for the future workforce.

The secondary objective concerns sustainability. It is now almost universally accepted that human activity must be sustainable. As many processes and raw materials must be considered in terms of Chemistry, considerations of Chemical Sustainability will be fundamental to the operations of all industries in the future. This course will encourage students to think about these ideas broadly.

The burning of forests in Indonesia to clear land to produce palm oil, a chemical feedstock has been the cause of the haze over several decades. The experience that Singapore has had with the haze over the years shows that issues arising from sustainability do not respect national boundaries, making this course highly appropriate for offering on an international basis.

**Intended Learning Outcomes (ILO)**

By the end of this course, you (as a student) will be able to:

**ILO1** – Work effectively in a multicultural and international team
**ILO2** – Demonstrate an understanding of the working methods of colleagues from outside Singapore
**ILO3** – Explain how chemical principles can be applied to solve problems of sustainability
**ILO4** - Apply chemical principles to a current issue of sustainability

**Course Content**

The course will be divided into two halves (some flexibility may necessarily have to be exercised)

1. Before Recess there will be a programme of lectures by experts from the three institutions covering important topics of chemical sustainability. These will include, but not be limited to:
*Water*
*Atmospheric Chemistry*
*Principles of Green Chemistry*
*Catalysis for Pharmaceutical Manufacturing*
*Clean Energy*
*Renewable Resources*

Topics will typically be timetabled for 3 hours. Means of delivery will be at the discretion of the expert lecturers and will reflect both their own preferences and also normal practices in the different countries. While it is to be expected that the majority of content will be delivered through traditional lectures, we will encourage lecturers to consider tutorial activities, discussion groups and other, more interactive methods. Depending on our ability to coordinate the timetables of three institutions in three time zones, we will seek to find a balance between synchronous and asynchronous delivery. We propose to use synchronous delivery where possible to allow for question-and-answer time after content delivery. While we can rely on some asynchronous delivery if timetabling obstacles cannot be resolved, we will ensure at least some synchronous time to allow for tutorial sessions, discussions groups and such activities.

Expert lecturers will also develop "curricular activities" based upon their content. These will again vary based upon the lecturer's preference. They will be a mixture of individual and group activities. They will include straightforward calculations (e.g., Green metrics), readings, discussion points, mini-presentations and so forth. Where these are to be done in groups, the students will work in the same international teams as for the second half of the semester so that these activities also work as "ice-breakers".

2. After recess week, the students will work in their teams on the projects. Each team will have two faculty mentors from different countries so that students will work with both students and faculty from other countries. This will lead up to team presentations and reports at the end of the semester.

**Assessment (includes both continuous and summative assessment)**

| Component | Course LO Tested | Related Programme LO or Graduate Attributes | Weighting | Team/ Individual | Assessment Rubrics |
|---|---|---|---|---|---|
| 1. Group working assessment | IL01 | Character, Communication | 10% | Individual (Note 1) | |
| 2. Reflection on multicultural experience | ILO2 | Character, Communication | 20% | Individual (Note 2) | |
| 3. Curricular Activities | ILO3 | Competence | 20% | Individual (Note 3) | |
| 4. Presentation | ILO4 | Competence, Creativity, Communication, Civic-Mindedness | 30% | Individual (Note 4) | |
| 5. Report | ILO4 | Competence, Creativity, Communication, Civic-Mindedness | 20% | Team (Note 5) | |
| Total | | | 100% | | |

Notes

1. Students will be asked to assess how well other students in their team worked. We will use an algorithm developed by Dr Fedor Duzhin, Division of MAS, for this purpose. Using this algorithm each member of the team will assess the contribution of each other member of the team, so that each student receives an individual grade. These grades will be checked by the team's faculty mentors. Dr Duzhin will assist with this activity.

2. Students will be asked to write a short essay on how their perceptions of Thailand and India changed as a result of this course. To do this, they must first describe their previous perceptions and experiences of these countries and cultures (if any), then analyse how their attitude changed (or did not change) as a result of working in the course. They will also compare different aspects of the three countries, especially the working styles, and comment on how the students of the three countries can learn from each other. The reflections will be graded by a small team drawn from the three institutions.

3. Expert lecturers will set a variety of curricular activities at their discretion which may be either individual or team based. As the expert lecturers will be drawn from the three countries involved, the activities will reflect the educational practices in each country, giving the students insight into how educational practices affect cultural differences. These activities will be graded by the individual lecturers.

4. While the presentation will be a group activity, it will be a requirement that both presentation and Q & A will be shared between all team members. In this way, grading of the overall presentation will be based upon the work of the group, but the NTU student will still be assessed based on their own share of the presentation and Q & A. In addition, students will be given additional credit for their participation in the Q & A session of other groups' presentations. Assessment will be done by a team of faculty members drawn from the three institutions.

5. The report will be prepared by the group. The Group Working Assessment and the observation of the faculty mentors will be used to ensure that all group members contributed equitably. The report will be marked by a small group of faculty members with expertise in the field and moderated by the course coordinators.

**Formative feedback**

During the first part of the course, students will be given regular feedback on their curricula activities by the expert lecturers. During the second part of the course, the students will work in teams with faculty members and will get ongoing feedback from their faculty mentors. Students will also receive final feedback on both their presentations and reports from mentors and assessors at the end of semester.

**Learning and Teaching approach**

**The Expert Lecturers**

The first part of the course will have lectures from experts in various fields so that students can appreciate the challenges of Chemical Sustainability and see how chemical principles have been applied in diverse fields. This is ILO3. Through the curricular activities, the students will be able to apply chemical principles to solve problems both individually and in groups. This part of the course will achieve several objectives:

1. to get the teams accustomed to working together
2. to begin the process of multicultural learning

3. to build a common foundation for the project work

**Group Working**
In the second part, the students will work in teams on a project which they will devised in consultation with their faculty mentors. We envisage a high degree of flexibility in the type of project. While a purely laboratory project is likely to be impractical, projects based upon simulation, design or review will be encouraged. This will directly meet ILO4. The experience of working in the team and with the faculty mentors will provide the experience to meet ILO1 and ILO2.

An essential pre-condition is team formation with each team having a student from Singapore, India, and Thailand. An online team forming exercise based on scientific interests will be carried out early in the semester so that the students will have the primary say in who is in their team.

Due to the highly collaborative nature of the course and the need for close interactions with students from other universities, interviews will be conducted by the course coordinator in week-1 before the add/drop deadline to select students who are suitable for this course. Students who apply for this course during course registration, before the interview selection, will initially be enrolled onto the waitlist. Students who are selected will subsequently be added to the course.

**Reading and References**

*Green Chemistry*, Paul C. Anastas and John C. Warner, Oxford University Press 2000
ISBN 0198506988, 9780198506980

**Course Policies and Student Responsibilities**

**(1) General**

You are expected to complete all assigned pre-class readings and activities, attend all classes punctually and take all scheduled assignments and tests by due dates. You are expected to fully participate in all group working and other activities. You will attend and participate in all presentations.

**(2) Absenteeism**

All assignments must be submitted on time. Students are advised to plan their time carefully so that they do not miss any deadlines.

**Academic Integrity**

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you

should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

**Course Instructors**

| Instructor | Office Location | Phone | Email |
|---|---|---|---|
| Roderick Bates | CBC-04-08 | 6316 8907 | roderick@ntu.edu.sg |

**Planned Weekly Schedule**

The timeline is for illustrative purposes and depends on alignment of the semesters of the three institutions.

| Week | Activities | Course LO |
|---|---|---|
| 1 | Introduction, interviews, and ice-breaking | |
| 2 | Expert Lectures (Green Chemistry) | ILO3,4 |
| 3 | Expert Lectures (Water Chemistry); team selection[1] | ILO3,4 |
| 4 | Expert Lectures (Catalysis) | ILO3,4 |
| 5 | Expert Lectures (Renewable resources) | ILO3,4 |
| 6 | Expert Lectures (Atmospheric Chemistry) | ILO3,4 |
| 7 | Expert Lectures (Energy) | - |
| Recess | Field trip to IIT Madras (optional) | ILO1,4 |
| 8 | Project work | ILO1,4 |
| 9 | Project work; field trip to Chulalongkorn University (optional) | ILO1,4 |
| 10 | Project work | ILO1,4 |
| 11 | Project work | ILO1,4 |
| 12 | Presentations | ILO2,3,4 |
| 13 | Presentations | ILO2,3,4 |

note 1: team selection is after the NTU add/drop period ends
note 2: the above schedule is for illustrative purposes only
note 3: presentations may extend into week 14 to accommodate the timetables of the other institutions

**CBC Programme Learning Outcome**

The Division of Chemistry and Biological Chemistry (CBC) offers an undergraduate degree major in Chemistry that satisfies the American Chemical Society (ACS) curricular guidelines and equips students with knowledge relevant to the industry. Graduates of the Division of Chemistry and Biological Chemistry should have the following key attributes:

**1. Competence**

Graduates should be well-versed in the foundational and advanced concepts of chemical science, be able to evaluate chemistry-related information critically and independently, and be able to use complex reasoning to solve emergent chemical problems.

**2. Creativity**

Graduates should be able to synthesize and integrate multiple ideas across the curriculum, and propose innovative solutions to emergent chemistry-related problems based on their training in chemistry.

**3. Communication**

Graduates should be able to demonstrate clarity of thought, independent thinking, and sound scientific analysis and reasoning through written and oral reports to audiences with varying technical backgrounds. They should also be able to effectively engage other professional chemists in collaborative endeavours.

**4. Character**

Graduates should be able to act in responsible ways and uphold the high ethical standards that the society expects of professional chemists.

**5. Civic-mindedness**

Graduates should be aware of the impact of chemistry on society, and how chemistry can be applied to benefit mankind. They should also be aware of and uphold the best chemical safety practices.