Annex A

3. GE NEW COURSE CONTENT

Academic Year	AY2023-2024	**Semester**	2
School/Programme	School of Materials Science and Engineering Doctor of Philosophy (MSE)		
Course Coordinator	Professor Cho Nam-Joon		
Course Code	MS7075		
Course Title	Bridging Sustainability and Materials Science: A New Paradigm		
Pre-requisites	None		
No of AUs	3		
Contact Hours	39 (3 hours per week – 2.5 hours of lecture, 0.5 hours of discussion)		
Proposal Date	22 August 2023		
Expected Implementation date of new/revised course	AY2023-2024 Semester 2		
Suggested Class Size	35		
Any cross-listing? ***Is course opened to all Postgraduate students (including IGP) or specific program (please indicate)?***	Master of Engineering (MSE) Master of Science (MSE) Doctor of Philosophy (IGP) Students from the above-stated programmes are not required to seek approval from MSE to be registered for the course.		

Course Aims

The course aims to integrate the principles of sustainability and materials science, fostering an in-depth understanding of nature-inspired materials and their potential to drive a new era of eco-friendly innovations. The course is specially tailored for postgraduate students who will lead the next generation of materials science innovators into the new economy based on the vision of beyond sustainability. Apart from providing valuable insight into emerging technologies surrounding the materials innovation landscape, it will more importantly highlight that materials innovation alone is insufficient for global sustainability. Hence, the course will instill a holistic perspective, encouraging you to think about broader systems and their impact, at the same time inculcating a deep sense of responsibility towards creating sustainable solutions for the future.

Intended Learning Outcomes (ILO)

By the end of this course, you should be able to:

1. Understand and appreciate the central role of sustainable materials development in driving the world economy.
2. Gain insight into emerging materials engineering and management strategies to achieve sustainability objectives.
3. Learn about materials life cycle based on the traditional linear economy and understand the shortfalls of the take-make-waste model.
4. Understand the rationale behind the recent emergence of the circular economy and its limitations in circumventing waste management issues, especially within the context of the plastic pandemic.

5. Understand the novel concept of cross economy, learn about keys aspects of cross dimensional technology, and understand their contribution towards economic diversification.
6. Gain technical knowledge and skills to transform nature-based materials into advanced engineering materials.
7. Understand how materials science and engineering principles guide the efficient use of natural resources to develop novel materials.
8. Appreciate the importance of sustainable processing within the context of materials synthesis, scale-up and production.
9. Develop the capability to envision new material applications extending from current efforts toward building a sustainable future.
10. Explore ways to innovate materials that can be diversified across an array of emerging applications.

Course Content

- History of Sustainable Materials
- Materials Innovation with Industrial Revolution
- Linear and Circular Economies
- Cross Economy and Cross-Dimensional Technology
- Translational Materials Innovation
- Sustainable Processing
- Materials Diversification for High-Value Applications

Assessment (includes both continuous and summative assessment)

Component	ILO Tested	Weighting	Team/Individual	Assessment Rubrics
1. Continuous Assessment 1 (CA1): Quiz (open-ended, short-answer questions)	1-5	40%	Individual	Appendix 1
2. Continuous Assessment 2 (CA2): Essay (proposal format)	6-10	60%	Individual	Appendix 2
Total		100%		

Description of Assessment Components:

CA1 Quiz: The quiz will be in an open-book format and the duration will be 1 hour. You will be required to respond to a series of open-ended questions that are aimed at assessing your understanding on the concepts of sustainability, materials innovation, cross economy and cross-dimensional technology. More broadly, this assessment will deepen your capacity to critically examine course readings (including specialized papers and reports on current and projected trends in sustainability) and to evaluate their arguments.

CA2 Essay: The essay will be in a proposal format. You will be required to write a proposal to address an outstanding problem in sustainability of your choice based on what you have read from the specialized papers and reports on current and projected trends in sustainability. Your proposal should offer solutions that are aligned to the cross economy model and using the concept of cross-dimensional technology.

Formative feedback

You will receive formative feedback through written responses to your Quiz and verbal feedback through in-class discussion. The responses to the open-ended questions of the Quiz will be thoroughly discussed in class and you will be provided with feedback on your approaches and thought process. The average grades for the Quiz will be posted and you will also be informed of your own grades so that you will have an idea of your standing among your peers and make improvements, when necessary. You are also strongly encouraged to drop by the coordinator's office during consultation hours to browse through special papers and reports on current trends in sustainability and discuss any outstanding issues, if needed. You will receive summative group feedback on the Essay following the conclusion of the module.

Learning and Teaching Approach

Approach	**How does this approach support you in achieving the learning outcomes?**
Conceptual understanding	As this course is a key course that bridges the concept of materials innovation to sustainability, there will be a lot of emphasis on fundamental understanding of the concepts and self-directed learning. Though lecture notes are provided to students, they are encouraged to refer different books, specialized papers, and reports on current trends in sustainability and their relation to existing economic models so that they gain a comprehensive understanding of the topic. Also, the systematic approach of starting at the basics of materials innovation and relating to processing methods, physiochemical characteristics and finally the applications using each characteristic of materials for sustainability applications will help students in grasping and appreciating the concept of bridging sustainability and materials science.
Showing real-world applications	Most of the concepts that are dealt in the course have real-world implications and applications. Therefore, they are used as examples while discussing the related concepts.
Blended learning with active use of multi-media resources (TEL)*	Multimedia tools such as videos and animations have been prepared exclusively for this course to help students better understand the contents. This will permit flexibility of access to learning materials, activities and assessments and can help you develop independent learning and critical thinking skills.
Face-to-face discussion sessions	For most part of the course, tutorials are replaced with discussion sessions that are designed to check and reinforce the students' understanding of various concepts. The questions posed during the discussion sessions will further clarify important concepts/principles covered in lectures and cultivate critical thinking.

Reading and References

Compulsory Reading Material:

- UN-SDG Goals

Supplementary Reading Materials:

- Introduction: Toward more inclusive definitions of sustainability PK Virtanen, 2020 – Elsevier
- Ben-Ali; Sustainability: definition and five core principles, a systems perspective. Sustainability Science, 2008, 13, 1337-1343
- Specialized papers and reports that will be circulated weekly, in advance of the lectures.

Course Policies and Student Responsibilities

(1) General
You are expected to complete all assigned pre-class readings and activities, attend all lecture and discussion sessions punctually, complete the quiz and submit your essay by the stipulated deadline. You are expected to take responsibility to follow up with course notes and course related announcements for lecture and discussion sessions you have missed. You are expected to participate in all in-class discussions and activities.

(2) Absenteeism
Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

If you miss a lecture, you must inform the course instructor via email prior to the start of the class.

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
Professor Cho Nam-Joon	RTP XF/06-05A	65927945	njcho@ntu.edu.sg

Industry Participation

Company Name	Description of involvement (e.g., co-curation of course, speaker or instructor), include no. of course hours if known.	Contact Person	Email
LUCA AICell (Seoul)	Guest lecturers Provided input and advised on the formulation of the course contents	Kim Taehoon	taehoonk79@gmail.com
JAPFA (Indonesia)		Gabriella Santosa	gabriella.santosa@japfa.com

Planned Weekly Schedule

Week	Topic	ILO	Readings/ Activities
1	History of Sustainable Materials	1,2	Lecture (2.5 hours) + Discussion (0.5 hours)
2	Materials Innovation with Industrial Revolution	1,2	Lecture (2.5 hours) + Discussion (0.5 hours)
3	Linear Economy and the Pitfalls of the Take-Make-Waste Model	3	Lecture (2.5 hours) + Discussion (0.5 hours)
4	Circular Economy: Where Are We Now?	4	Lecture (2.5 hours) + Discussion (0.5 hours)
5	Advent of Cross Economy	5	Lecture (2.5 hours) + Discussion (0.5 hours)
6	Materials Sustainability in Cross Economy	5	Lecture (2.5 hours) + Discussion (0.5 hours)
7	Cross-Dimensional Technology	5	Lecture (1 hours) + Quiz (2 hour)
8	Novel Materials Research and Development	6	Lecture (2.5 hours) + Discussion (0.5 hours)
9	Translational Materials Innovation	6	Lecture (2.5 hours) + Discussion (0.5 hours)
10	Sustainable Processing: Materials Synthesis	7,8	Lecture (2.5 hours) + Discussion (0.5 hours)
11	Sustainable Processing: Scale-up and Production	7,8	Lecture (2.5 hours) + Discussion (0.5 hours)
12	Materials Diversification for High-Value Applications	9,10	Lecture (2.5 hours) + Discussion (0.5 hours)
13	Pollen as a Case Study	4-10	Lecture (2.5 hours) + Discussion (0.5 hours)

Appendix 1: Assessment Criteria for CA1 Quiz

The Quiz will have open-ended questions that are designed to assess the student's performance based on the five criteria below. Each set of questions that assess a particular criterion will carry a minimum mark of 1 and a maximum mark of 10. The total maximum mark for the Quiz is 50. The quality of the student's responses will be graded based on the distribution below, except if they do not provide any response at all, in which they will be awarded zero point.

Criteria	Unsatisfactory (1-2)	Satisfactory (3-5)	Good (6-8)	Exemplary (9-10)
Conceptual Understanding	Unable to demonstrate basic understanding on any of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates moderate understanding on some of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates moderate understanding on most of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates excellent understanding on most if not all of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology
Subject Knowledge	Unable to demonstrate basic knowledge on the subject matter	Demonstrates intermediate knowledge on the subject matter	Demonstrates good knowledge on the subject matter	Demonstrates excellent knowledge on the subject matter
Argumentative Response Articulation	Unable to respond to open-ended questions with proper terms used in the subject	Demonstrates basic ability to respond to open-ended questions with proper terms used in the subject	Demonstrates good ability to respond to open-ended questions with proper terms used in the subject and valid arguments	Demonstrates excellent ability to respond to open-ended questions with proper terms used in the subject and presents valid arguments with fresh viewpoints
Evidence-Based Reasoning	Unable to justify responses and present with basic evidence	Able to justify some responses with appropriate evidence	Able to justify most responses with good evidence	Able to justify all responses with solid evidence
Translational Capability	Unable to grasp and apply any concept of translation within the context of materials innovation in sustainability	Able to grasp and apply some concepts of translation within the context of materials innovation in sustainability	Able to grasp and apply most concepts of translation within the context of materials innovation in sustainability	Demonstrates excellent grasp of all concepts of translation within the context of materials innovation in sustainability

Appendix 2: Assessment Criteria for CA2 Essay

The Essay will be in a proposal format, in which the students are required to write a proposal to address an outstanding problem in sustainability of their choice based on what they have read from the specialized papers and reports on current and projected trends in sustainability. The proposal should offer solutions that are aligned to the cross economy model and using the concept of cross-dimensional technology. The Essay will assess the student's performance based on the five criteria below. The quality of the student's essay will be graded based on the distribution below, except if they do not submit the Essay at all, in which they will be awarded zero point.

Criteria	Unsatisfactory (1-2)	Satisfactory (3-5)	Good (6-8)	Exemplary (9-10)
Conceptual Understanding	Unable to demonstrate basic understanding on any of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates moderate understanding on some of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates moderate understanding on most of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology	Demonstrates excellent understanding on most if not all of the concepts of sustainability, materials innovation, cross economy and cross dimensional technology
Subject Knowledge	Unable to demonstrate basic knowledge on the subject matter	Demonstrates intermediate knowledge on the subject matter	Demonstrates good knowledge on the subject matter	Demonstrates excellent knowledge on the subject matter
Problem Identification	Unable to identify an appropriate problem	Demonstrates basic ability to identify a common materials problem with minimal significance to sustainability	Demonstrates good ability to identify a materials problem with considerable significance to sustainability	Demonstrates excellent ability to identify an urgent materials problem with immediate real-world implications within the context of sustainability
Novelty of Proposed Solutions	Unable to propose a feasible solution to the identified problem	Able to propose a feasible solution to the identified problem using a common existing approach	Able to propose a good solution to the identified problem using a rare but existing approach	The solution proposed to the identified problem is novel or ingenious
Overall Organization and Quality of Proposal	Proposal is disorganized with poor flow	Proposal is organized with clear structure	Proposal is well-organized with good structure and readability	Proposal organization and readability is excellent with smooth flow and structure