Bachelor of Science (Data Science and AI)
Final Year Cores and Major Prescribed Electives

DSAI Core	Semester Offered		AU	Pre-requisite*
	SEM 1	SEM 2		
CZ4032 Data Analytics and Mining	√		3	CZ2001
CZ4041 Machine Learning	√	√	3	CZ1107 & MH2500 or CZ1007 & MH2500
CZ4042 Neural Networks & Deep Learning	√	√	3	CZ1107 & MH2802 or CZ1007 & MH2802
DSAI MPEs	**Semester Offered**		**AU**	**Pre-requisite***
	SEM 1	**SEM 2**		
CZ4010 Applied Cryptography	√		3	MH2500
CZ4031 Database System Principles	√	√	3	CZ2001 & CZ2007
CZ4034 Information Retrieval		√	3	CZ2101 or CZ2001
CZ4045 Natural Language Processing	√		3	CZ2001
CZ4046 Intelligent Agents		√	3	CZ1107 & MH2500
CZ4123 Big Data Management		√	3	CZ2007
CZ4124 Data Visualisation	√		3	CZ1003 & MH2500 or CZ1103 & MH2500
CZ4125 Developing Data Products	√		3	CZ1016 & MH2500
CZ4052 Cloud Computing		√	3	CZ1104 & MH2802
CZ4071 Network Science		√	3	CZ2101 or CZ2001
MH3510 Regression Analysis	√		4	MH2500 & MH3500
MH3701 Basic Optimization		√	4	MH1201 or MH2800 or MH2802
MH4500 Time Series Analysis		√	4	MH2500 & MH3500 & MH3510
MH4501 Multivariate Analysis		√	4	MH2500 & MH3500 & MH3510
MH4511 Sampling & Survey	√		4	MH2500 & MH3500
MH4513 Survival Analysis	√		4	MH2500 & MH3500 & MH3510
MH4515 Applied Bayesian Statistics		TBC	4	TBC
MH4516 Applied Categorical Data Analysis		TBC	4	TBC
MH4517 Data Applications in Natural Sciences		√	4	MH1402 or MH1403 or CZ2001
MH4518 Simulation Techniques in Finance	√		4	MH2500 & MH3511
CS4022 Social Media Mining	√		4	CZ4032
CS4031 Media Planning and Strategies		TBC	4	(Year 3 Standing)

*In addition to the Pre-requisite shown here, student also needs to be of at least Study Year 3 standing.

SCSE MPEs Can be taken as UE if meet pre-requisite	Semester Offered		AU	Pre-requisite*
	SEM 1	SEM 2		
CZ4001 Virtual and Augmented Reality		√	3	(Year 3)
CZ4003 Computer Vision	√		3	(Year 3)
CZ4015 Simulation and Modelling		√	3	CZ1107 & MH2500 or CZ1007 & MH2500
CZ4016 Advanced Topics in Algorithms	√		3	CZ2001
CZ4055 Cyber Physical System Security		√	3	CZ1106 or CZ1006
CZ4062 Computer Security	√	√	3	CZ2005
CZ4064 Security Management	√		3	CZ2006
~~CZ4067 Software Security~~		~~√~~	~~3~~	~~CZ2002 & CZ2005~~
CZ4069 Concepts and Techniques for Malware Analysis		√	3	(Year 3)
CZ4070 Cyber Threat Intelligence	√		3	CZ1006 & CZ2005
CZ4052 Cloud Computing		√	3	CZ1004 or CZ1104
CZ4153 Blockchain Technology	√		3	CZ1107 & CZ2001 & MH1812 Or CZ1107 & CZ2101 & MH1812

*In addition to the Pre-requisite shown here, student also needs to be of at least Study Year 3 standing.

Note: This list will be update in subsequent Semester or AY when needed

CZ4032 – Data Analytics and Mining

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Cong Gao (gaocong@ntu.edu.sg) Lin Guosheng (gslin@ntu.edu.sg)					
Course Code	CZ4032					
Course Title	Data Analytics and Mining					
Pre-requisites	CE/CZ2001-Algorithms Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	26	Tutorials	11	Student Presentations	4

Course Aims

In the era of big data, large quantities of data are being accumulated. The amount of data collected is said to double every nine months. Seeking knowledge from massive data is one of the most desired attributes of Data Mining. In general, there is a huge gap from the stored data to the knowledge that could be construed from the data. This transition will not occur automatically, that is where Data Mining comes into picture. In Exploratory Data Analysis, some initial knowledge is known about the data, but Data Mining could help in a more in-depth knowledge about the data. Courses on Database systems give methods to extract information, but they fail to extract knowledge that is actionable.

Manual data analysis has been around for some time now, but it creates a bottleneck for large data analysis. Fast developing computer science and engineering techniques and methodology generates new demands. Data mining techniques are now being applied to all kinds of domains, which are rich in data. Although data mining is partly based on statistical methods, data mining methods give a lot more than the statistical methods. Data mining methods are to a large extent based on machine learning methods. The difference is data mining is meant for huge data whereas machine learning is usually done over relatively small-sized data. Huge data brings completely a new set of problems to be solved.

This course aims to introduce you to the exciting and ever-evolving world of data analytics and mining.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Discuss basic concepts and general knowledge of data analytics, data mining and the KDD process, using professional language associated with data analytics and data mining
2. Pre-process the data so that it can be analysed further using sophisticated data analytics and mining algorithms
3. Discuss several major data mining tasks (including classification, clustering, and association rule mining, etc) and related algorithms to solve them
4. Apply data mining techniques to tackle real-world big data applications, to perform core data
5. analytics & mining tasks with large amount of data.

Overview of Course Content

	Topics
1	**Introduction of Data Analytics & Mining** Overview of data mining and knowledge discovery, MapReduce and Spark.
2	**Data Cleaning and Integration** Data Warehouse, data cleaning, integration, entity resolution, discretisation, similarity measures
3	**Association Rule Mining** Frequent itemset generation, Association Rule, A-priori algorithm, FP-Growth algorithm, Sequential pattern mining, Rule based classification methods
4	**Classification** Decision tree, Ensemble Classification
5	**Recommendation Systems** Applications of Recommendation Systems, Content-Based, Collaborative Filtering, Latent Factor Models
6	**Locality-Sensitive Hashing**
7	**Clustering and Anomaly Detection** Clustering algorithms (choose from: K-means, k-mean++, BFR, CURE, Dbscan, etc) and anomaly detection algorithms
8	**Graphs Mining** Pagerank/random walk, Clustering/partitioning of Graphs, Discovery of Communities
9	**Graph Representation Learning and GNN** High-level introduction to deep learning, graph representation techniques, GNN
10	**Data Stream Mining** Filtering, querying
11	**Advanced Topic** One of the following topics: Computational advertising, Time series mining, Spatial temporal data mining

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Course Written Report and Presentation	50%	Team
Total	100%	

CE/CZ4041 – Machine Learning

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Sinno Jialin Pan (sinnopan@ntu.edu.sg) Kelly Ke Yiping (ypke@ntu.edu.sg)					
Course Code	CE/CZ4041					
Course Title	Machine Learning					
Pre-requisites	CE/CZ1011 or CE/CZ1004 & CE/CZ2100 CE/CZ1007 Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	22	Tutorials	10	Student Presentations	6

Course Aims

This course provides an introductory but broad perspective of machine learning fundamental algorithms, and is relevant for anyone pursuing a career in AI or Data Science. It aims to provide you with the essential concepts and principles of algorithms in machine learning so that you can use various machine learning techniques to solve real-world application problems.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Explain the motivations and principles behind various machine learning algorithms.
2. Apply or even design specific machine learning algorithms to solve real-world application problems.
3. Identify some state-of-the-art machine learning techniques.
4. Conduct research on machine learning.

Overview of Course Content

	Topics
1	**Introduction to Machine Learning** Overview of machine learning, supervised learning, unsupervised and applications
2	**Bayesian Classifiers** Bayesian decision theory, Naïve Bayes, Bayesian Brief Networks
3	**Decision Tree** Tree induction, prediction-based trees, generalisation errors
4	**Artificial Neural Networks** Perceptron, Multi-layer perceptron, backpropagation algorithm
5	**Support Vector Machines (SVMs)** Induction of SVMs, linear SVMs, Kernelised SVMs
6	**Regression Models** Linear regression, Kernelised regression
7	**K-Nearest Neighbor Classifiers (KNN)** KNN with majority voting, KNN with distance-weighted voting
8	**Ensemble Learning** Boosting, bootstrapping, model average
9	**Clustering** K-means clustering, hierarchical clustering, performance evaluation for clustering, applications
10	**Density Estimation** Parametric and non-parametric density estimation approaches
11	**Dimension Reduction** Principal component analysis (PCA), linear discriminant analysis (LDA)
12	**Application and Advanced Research Topics** Through course project on a predefined list of applications or research topics

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	60%	Individual
2. Course Project Presentation	10%	Team
3. Course Project Report	30%	Team
Total	100%	

CE/CZ4042 – Neural Networks and Deep Learning

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Jagath Rajapakse (asjagath@ntu.edu.sg) Loy Chen Change (ccloy@ntu.edu.sg)			
Course Code	CE/CZ4042			
Course Title	Neural Networks and Deep Learning			
Pre-requisites	CE1007, CE1011, CE1012 (AY19-20 and earlier cohort) or CZ1007, CZ1011, CZ1012 (AY19-20 and earlier cohort) or CE1107, CE1104 (AY20-21 cohort) or CZ1007, CZ1104, (AY20-21 cohort) or CZ1007, MH2802 (DSAI cohort) or CZ1107, MH2802 (DSAI AY20-21 Cohort); Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	12

Course Aims

This course aims to provide you with a basic but comprehensive foundation of neural networks and deep learning, including underlying principles, architectures, and learning algorithms of various types of deep neural networks that are essential for future applications of artificial intelligence and data science.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Interpret artificial neuron as an abstraction of biological neuron and explain how it can be used to build deep neural networks that are trained to perform various tasks such as regression and classification.
2. Identify the underlying principles, architectures, and learning algorithms of various types of neural networks.
3. Select and design a suitable neural network for a given application.
4. Implement deep neural networks that can efficiently run on computing machines.

Overview of Course Content

	Topics
1	**Introduction to Neural Networks** Biological neural networks, artificial neuron, activation functions, history of neural networks
2	**Regression** Gradient descent learning, stochastic gradient descent learning, linear neuron, linear regression, perceptron, perceptron learning algorithm
3	**Classification** Pattern recognition, discrete perceptron, discrete perceptron learning, logistic regression, learning a logistic neuron
4	**Neuron Layers** Softmax layer, softmax learning algorithm, perceptron layers, learning algorithms
5	**Feedforward Networks** Feedforward neural networks, multilayer perceptron, backpropagation algorithm, deep feedforward neural networks
6	**Model Selection and Overfitting** Holdout method, K-split resampling technique, K-fold cross-validation, three-way data splits, overfitting and underfitting of neural networks, early stopping, regularisation and weight decay, drop-outs
7	**Convolution Neural Networks (CNN)** Feature extraction by convolution, pooling of feature maps, convolutional neural networks, deep CNN, learning with momentum
8	**Recurrent Neural Networks (RNN)** Recurrent neural networks with hidden recurrence (Elman type) and with output recurrence (Jordan type), learning deep RNN
9	**Gated Recurrent Networks (GRN)** Vanishing and exploding gradient problem in RNN, memory cells and gating, long short-term memory (LSTM) units, gated recurrent units (GRU), sequence-to-sequence models
10	**Autoencoders** Learning of autoencoders, denoising autoencoders, sparse autoencoders, building stacked and deep autoencoders
11	**Generative Adversarial Networks** Generative models, discriminator and generator minmax game, training GAN, DCGAN, cGAN
12	**Revision**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	40%	Individual
2. Assignment (Programming)	25%	Individual
3. Project	35%	Team, scaled with Peer review for individual
Total	100%	

CE/CZ4010 – Applied Cryptography

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Tay Kian Boon (kianboon.tay@ntu.edu.sg)			
Course Code	CE/CZ4010			
Course Title	Applied Cryptography			
Pre-requisites	CE/CZ1011 or CE/CZ2100 Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	12

Course Aims

Summary: Cryptography is the foundational building block of Cybersecurity and Privacy. While the field of classical cryptography dealt with security and privacy of data in transit, the modern take on the subject has generalised the scope of its applications to ensuring security and privacy of all forms of digital communication, computation, automation, interaction, transaction and preservation. Thus, it is important to understand the technical aspects of cryptography to appreciate its applications in cybersecurity.

The Aim: This cryptography course in Computer Science and Engineering aims to develop your ability to understand how cryptographic algorithms work, to identify the problems associated with the application of cryptography in real-world scenarios, and explain the operation of various cryptographic mechanisms. This course will equip you to know deeply the fundamentals of symmetric key ciphers, hash functions and public key ciphers, enabling you to understand and develop secure cryptography solutions in real life cryptography. It will also introduce you to popular cryptographic libraries and APIs for hands-on implementation of security mechanisms, and some prominent cryptographic standards, guidelines and frameworks from the industry and government bodies.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Explain and analyse the design and construction of fundamental cryptographic algorithms.
2. Discuss and explain the construction of cryptographic mechanisms based on the algorithms.
3. Design and develop basic security applications using open cryptographic libraries and APIs.
4. Analyse and argue the applicability of cryptographic schemes in certain real-world systems.
5. Examine and describe the importance of cryptographic standards, guidelines and frameworks in practice.

Overview of Course Content

	Topics
1	**Introduction to Cryptography** Network Security, Computer Security and System Security and the connection of Cryptology; Related concepts: Steganography, Cryptanalysis; Cryptography Terminology: Encrypt, decrypt, plaintext, ciphers, keys & keyspace, cryptography, cryptanalysis, cryptology; Historical Cryptography: Caesar (Monoalphabetic) Ciphers, Vigenere (Polyalphabetic) Ciphers, Electromechanical Encryptor e.g. ENIGMA; Random Numbers, pseudorandom number generators, NIST tests for randomness; Modern Cryptography
2	**Symmetric (Private) Key Cryptography** Concept of one-time pad; Introduction to stream ciphers –Ciphers based on Linear Feedback Shift Register, RC4 cipher; Introduction to Block Ciphers (DES, AES)-Secure Implementations of Symmetric Key Cryptosystems; Key Agreement & key Management; Modes of operation for Encryption (e.g. ECB, CBC modes) and Message Authentication (CBC-MAC, HMAC)
3	**Hash Functions (unkeyed)** Concept of checksum, message digest, digital signatures; Hash Function Concept (one way hash, collision resistance, birthday attack}, MD5, SHA1, SHA-256, KECCAK
4	**Symmetric Cryptography in Practice (e-learning)** E.g. Open Libraries (NaCl) and APIs (PKCS11, Microsoft CSP); Efficient implementation of File Encryption using the APIs/Libs.
5	**Asymmetric (Public) Key Cryptography** Concept of Public Key Cryptography; Design ideas based on Hard Problems (Factoring, Discrete Log); Diffie-Hellman Key Exchange; Design and construction of Public Key Encryption-RSA cryptosystem; Implementing RSA cryptosystem securely; Comparison of Key Lengths recommended for the constructions; Introduction to Elliptic Curve Cryptography (ECC)
6	**Digital Signatures** Concept of Digital Signature in asymmetric key cryptography; Design and construction of Digital Signature schemes (RSA, DSA)
7	**Other Cryptographic Mechanisms** Introduction to secret sharing schemes; Introduction to Side Channel Attacks
8	**Introduction to Quantum Cryptography & Post Quantum Crypto Algorithms** Key Exchange using quantum cryptography; Post quantum crypto algorithms-e.g. NTRU
9	**Cryptographic Standards/Topics** SSL/TLS Transport Layer Security protocol-Some Weak TLS Implementations of crypto algorithms & protocol in real world; Some Cryptographic algorithm standards (e.g. ISO/IEC, NIST); Industry standards/guidelines, e.g., Banking (ANSI, ISO, MAS); Security Frameworks like CCITT, ISO/IEC, IETF, PKCS, etc.
10	**Other Practical Concerns** Open Libraries (OpenSSL) and APIs (PKCS11, Microsoft CSP); Dealing with crypto vendors – need for crypto acceptance tests

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1.Quiz	30%	Individual
2. Project	30%	Team and Individual
3. Final Examination	40%	Individual
Total	100%	

CE/CZ4031 – Database System Principles

Academic Year	AY2022-2023	**Semester**	1 & 2	
Instructor(s)	Long Cheng (c.long@ntu.edu.sg) Sourav S Bhowmick (ASSourav@ntu.edu.sg)			
Course Code	CZ4031			
Course Title	Database System Principles			
Pre-requisites	CZ2007: Introduction to Databases Study Year 3			
Pre-requisite for	CZ4033: Advanced Data Management			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

Database management systems (DBMS) are designed to manage large and complex data sets. The fundamentals of the implementation of database management systems must be understood by all Computer Science students. This will help students to develop and design software systems utilising databases, and equip students with the knowledge of managing data of large scale. Moreover, this should be understood by current and future business leaders so that they can offer strategic guidance based on an informed understanding of database business capabilities. This course provides the basis for achieving this goal.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Discuss the importance of, and uses for, databases within organisations.
2. Explain how a relational database is implemented.
3. Describe the principles behind commercial databases and how to manage a relational database system.
4. Communicate knowledgeably about data management using professional language.

Overview of Course Content

	Topics
1	**Overview of Database Management Systems (DBMS)** DBMS Architecture, Relational DBMS
2	**Storage of Relational Data** Memory Hierarchy, Disks, Representing Relations in Disks, Using Secondary Storage Effectively, How to Move Data to Memory
3	**Indexing Techniques** Indexes on Sequential Files, Secondary Indexes, B-Trees, Hashing, Multi-dimensional Indexes (R-Trees, kD Trees)
4	**Query Processing** One-Pass Algorithms, Nested-Loop Joins, Two-Pass Algorithms based on Sorting and Hashing, Index-Based Algorithms, Algebraic Laws
5	**Query Optimisation** Introduction to Physical Query Plan Operators, Logical Query Plans, Physical Query Plans, Join Ordering
6	**Failure Recovery** Modelling Resilient Operations, Undo/Redo Logging, Checkpoint, Recoverability, Recovery process
7	**Transaction Management and Concurrency Control** Transactions, Serial and Serialisable Schedules, Conflict-Serialisability, Locking, Resolving Deadlocks

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quizzes (Three)	60%	Individual
2. Projects (Two)	40%	Team and individual
Total	100%	

CE/CZ4045 – Natural Language Processing

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Sun Aixin (axsun@ntu.edu.sg) Joty Shafiq (srjoty@ntu.edu.sg)			
Course Code	CE/CZ4045			
Course Title	Natural Language Processing			
Pre-requisites	CE/CZ2001 Algorithms Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials/Example Classes	13

Course Aims

Natural language processing is becoming a very hot topic in both industrial practices and academic research. It finds many real-world applications such as information extraction, sentiment analysis, machine translation, question answering, and summarisation. Hence, it is an important subject to prepare you to cope with the huge amount of unstructured information in text, for example, in web pages and business documents. This subject covers the basic concepts and computational methods for natural language processing. Techniques covered should be biased toward those generally accepted established traditional practices recommended by practitioners.

This course will equip you with the basic concepts and techniques in natural language processing on different levels including words, syntax, and semantics. You will be able to apply the techniques to real-world problems and conduct evaluations of your solutions.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Identify and analyse the linguistic characteristics of written English.
2. Design and develop an NLP system to analyse and process a general corpus.
3. Troubleshoot for domain-specific NLP applications.

Overview of Course Content

	Topics
1	**Regular Expressions and Word-Level Analysis** Introduction to NLP, Finite State Automata (Deterministic and Non-deterministic), Stemming, Tokenising, Segmentation, Spelling Checking
2	**N-gram Language Model** Word Prediction, N-gram Language Models (Counting and basic concepts), Evaluation, Smoothing for Language Models
3	**Word Classes and Part-of-speech Tagging** Word classes, POS tagging, Hidden Markov Model and its Application to Part-of-speech Tagging, the Viterbi Algorithm
4	**Formal Grammars** Constituency, grammatical relations, subcategorisation, phrase structure, dependency structure, context free grammar (CFG), dependency grammar
5	**Syntactic Parsing** Top-down parsing, bottom-up parsing, parse tree, CKY algorithm, Earley algorithm, syntactic ambiguities, probabilistic CFG, treebank, attachment ambiguities, lexicalised CFG
6	**Computational Semantics** First-order logic, model-theoretic semantics, representing linguistic concepts, semantic augmentation to CFG, compositional semantic analysis
7	**NLP Applications** Introduction to Classification Methods, Evaluation, Introduction to Sentiment Analysis (Concept and Basic Methods). Information extraction. Word sense disambiguation
8	**Machine Translation** Introduction to Machine translation (Alignment Models, Decoding)
9	**Review**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Midterm Quiz	15%	Individual
3. Assignment	35%	Team
Total	100%	

CZ4124 – Data Visualisation

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Goh Wooi Boon (ASWBGOH@ntu.edu.sg)					
Course Code	CZ4124					
Course Title	Data Visualisation					
Pre-requisites	CZ1103 Introduction to Computational Thinking & Programming MH2500 Probability and Introduction to Statistics OR CZ2100 Probability and Statistics for Computing Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	26	Tutorials	13	Laboratories	-

Course Aims

The data visualisation course aims to provide computer science-oriented students with the principles and practice to design and present effective data visualisation solutions for different datasets and visualisation objectives. The course focuses on applying design considerations which take into account the human's visual and psychological characteristics, with the goal of designing effective and ethical visuals. The course also introduces students to the large variety of techniques and tools for visualising, exploring and interacting with both abstract and scientific data.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Describe the various types of data and its effective visual encoding in data visualisation.
2. Describe, design and evaluate the appropriate plots and charts commonly used in visualising, interacting and exploring different datasets.
3. Describe how various human visual perception characteristics can be considered in the design of effective visuals.
4. Describe various techniques for visualising abstract and scientific datasets
5. Describe techniques and tools for delivering data visualisation solutions in different application domains.

Overview of Course Content

	Topics
1	**Introduction** What data visualisation is and why it is important. What is needed to produce good data visualisation. The process and considerations in the practice of data visualisation. Examples of good and poor data visualisation.
2	**The Data – Their Attributes and Representations** Types of data - nominal, ordinal and quantitative (discrete and continuous), temporal and spatial. Dimensions and measures. Data dimensionality, Hierarchical data. Relational & statistical data models, tables, representation, etc. Data wrangling. Datasets and formats.
3	**The Visual – Visual Encoding** Visual encoding variables. Design space of visual encoding, Mackinlay – formalising design, criteria, ranking, algorithm and limitations, Visual encoding examples.
4	**Visualisation Tools** Categories of visualisation tools. Choosing the most appropriate tool for the task. Brief survey of popular data visualisation tools and packages. Introducing tools to be used in the course. Visualisation demo examples.
5	**Basic Plots and Charts** Comparison plots (line, bar and radar charts). Relation plots (scatter & bubble plots, correlogram, heatmap). Composition plots (pie, stacked bar, stacked area charts, Venn diagram). Distribution plots (histogram, density, box, violin plots). Scales, smoothing, locally weighted regression (loess), visual reference grids, conditioning (coplot), statistical variation, etc.
6	**Visual Perception in Data Visualisation** Change detection and blindness (Weber's law). Estimating magnitude (Steven's power law) and rate of change. Pre-attentive and attentive visual processing. Perceiving multiple attributes. Gestalt grouping. Layering. Colour perception. Visual motion and animation. Case studies of good and poor visual designs.
7	**Designing the Visualisation** Getting started – the visualisation design process. Psychological principles of effective visualisation. Case study examples – improving visual design to tell the right story. Common mistakes in visualisation designs. Ethical visualisation.
8	**Interactive Visualisation** The why and when of interactive visualisation. Interaction techniques (selection/annotation, dynamic queries, sorting, navigation, brushing and linking). Interaction controls (GUI widgets, direct manipulation, etc). Advanced interactivity visualisation (VR, immersive visualisation, etc)
9	**Exploratory Data Analysis and Visualisation** Differences between exploratory and explanatory visualisation. Iterative exploration and data transformation. Combining visualisation and statistical analysis.
10	**Visualisation of Abstract Data** Information visualisation. Visualisation of relationships (trees and graphs). Text visualisation. Geo data visualisation (dot map, choropleth map, connection map).
11	**Visualisation of Scientific Data** Scalar visualisation. Image visualisation. Vector Visualisation. Tensor Visualisation. Volume Visualisation
12	**Data Visualisation Applications** Data visualisation business and trends. Data visualisation dashboard (tools, design and considerations). Case studies of data visualisation applications. Tableau demo and examples.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Project	40%	Individual and Team
2. Critique of Presentations	20%	Individual
3. Quiz	40%	Individual
Total	100%	

CZ4125 – Developing Data Products

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Anwitaman DATTA (anwitaman@ntu.edu.sg)			
Course Code	CZ4125			
Course Title	Developing Data Products			
Pre-requisites	CZ1016 (Introduction to Data Science) MH2500 (Probability and Introduction to Statistics) Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	20.5	Lab	22

Course Aims

Data products are products whose principal thrust is to use data to facilitate certain end goals. These products may exhibit varied levels of complexity, spanning from being raw and derived data, intelligence and services derived from or driven by data, enabled by algorithmic and statistical tools such as machine learning. In many data products, the role of data can be subtle, and the overall product may be composed of other modules, which could be more prominent in appearance.

The scope of this course is confined to the exploration of the life-cycle of typical data products that deploy data-science dominantly or exclusively. We will deconstruct individual components across the full stack: ranging from data acquisition, wrangling and storage, testing, validation, and refinement - spanning exploratory analysis, issues of visualisation and presentation, and application of machine learning techniques for decision support, anomaly detection and recommendation systems. We will explore this course with hands-on examples, illustrating how some data products utilise only a subset of these components, while others deploy the wider gamut.

This course will also expose techniques to handle various kinds of data on their own and in conjunction, e.g., natural language data, datetime and timeseries, geoseries and graph data; the underlying systems and algorithms to support, analyse and learn using such data to build data products.

The course will be delivered inter-mixing live lectures and hands-on exercises blended with some parts of the lectures offered in pre-recorded TEL format and curated reading materials.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Use data analytics, machine learning and visualisation tools in stand-alone manner, as well as together for developing data products.
2. Deal with multiple data sources and multiple kinds of data.
3. Identify and use suitable tools for realising specific data product features.
4. Design the overall workflow spanning the life cycle of data products.
5. Validate and represent results correctly taking into consideration usability issues.
6. Carry out product requirement analysis, ideate, and implement data products.

Overview of Course Content

	Topics
1	**Introduction** What are data products? The development cycle of data products, how it fits in the big picture of data science, AI, big data; What to expect/not to expect from this course? What is expected of the students from this course? Relation with other courses in the program; Logistics issues, e.g., assessments plan, familiarisation with the lab setup
2	**Basic Data Structures and Data Manipulation** Review of some Python essentials; Data frames and data series, e.g., using Pandas; Regular expressions
3	**Visualisation** Technical tools, e.g., Matplotlib, Seaborn; Ethical, usability and aesthetics issues, e.g., Identify and avoid creating misleading visuals, keep the visuals informative but avoid clutter; Accessibility issues, e.g., create visuals accounting for colour blindness; Dynamic and interactive visualisation; Example visualisations
4	**Data Acquisition and Munging/Wrangling** Scraping tools; Interacting with a database; Combining multiple datasets, dealing with missing data, tidy data
5	**Principles of Product Design and Validation** Some general-purpose approaches for design and validation of products, e.g., A/B testing, statistical tests
6	**Applying Machine Learning Tools** Brief overview of some essential algorithms, e.g., Clustering, Classification, Regression; Brief overview of essential software libraries, e.g., Scikit-learn; Application use-cases, e.g., prediction, decision support, recommendation systems
7	**Applying Text Processing Tools** Brief overview of some essential concepts, e.g., natural language processing, topic modelling; Brief overview of essential software libraries, e.g., NLTK; Application use-cases
8	**Graph Data Analytics** Concepts and overview of algorithms; Essential software libraries, e.g., NetworkX
9	**Dashboards and Web-Based Applications** Essential software libraries to create dashboards and web-based applications
10	**Big Data Infrastructure** Overview of selected big data tools and specialised databases, e.g., one or several of MapReduce, BigQuery, MongoDB, Neo4j, Solr
11	**Privacy and Security Issues** Legal and regulatory aspects, e.g., personally identifiable information; Technical concepts, e.g., data anonymization (and example software tools), secure computation
12	**Real World Case-Studies** Case studies: Lectures either by faculty teaching the course, or by guest lecturers who are industry practitioners, or third-party videos by practitioners vetted and curated by the course coordinator, detailing the experiences from development and deployment of recent/timely real-world data products and associated tools.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Lab Quizzes	30%	Individual
2. Lab Assignments	30%	Individual
3. Capstone	40%	Team and Individual
Total	100%	

CE/CZ4034 – Information Retrieval

Academic Year	AY2022-2023	**Semester**	2	
Instructor(s)	Erik Cambria (cambria@ntu.edu.sg)			
Course Code	CZ4034			
Course Title	Information Retrieval			
Pre-requisites	Data structures, algorithm; Linear algebra, probability. Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	23	Tutorials	8

Course Aims

This course aims to involve students in a technical way to understand and build information retrieval systems. They were expected to master the basic concepts and building blocks for information retrieval systems. In addition, applications in artificial intelligence were also introduced to get students acquainted with state of the arts.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. List and explain each of the modules information retrieval system.
2. Code with necessary packages to build a preliminary search engine.
3. Describe and distinguish various retrieval systems.
4. Apply fundamental clustering, classification and web search techniques to solve problems, such as computations and designs.

Overview of Course Content

	Topics
1	**Introduction to Information System** Course details and schedule. General introduction to definition and application to information system.
2	**Boolean Retrieval and Tolerant Retrieval** Term-document incidence; Inverted index; Boolean query; Optimisation; Tokenisation; Linguistic analysis; Query.
3	**Ranked Retrieval** Term-document count matrix; tf-idf; Vector space ranking.
4	**Efficient Retrieval** Efficient vector space representation; Efficient cosine ranking; Computing the K largest cosine values; Parametric and zone indexes; Tiered indexes.
5	**Enhancing Retrieval** Evaluation, calculating F-measure; Options for improving results using global and local methods.
6	**Classification** Text classification; Techniques; Feature selection.
7	**Clustering** Document clustering; Clustering algorithms.
8	**Web search and IR applications** Web search; Link analysis.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Assignment	35%	Team
3. Quiz	15%	Individual
Total	100%	

CE/CZ4046 – Intelligent Agents

Academic Year	AY2022-2023	**Semester**	2	
Instructor(s)	Bo An (boan@ntu.edu.sg) Zhang Jie (zhangj@ntu.edu.sg)			
Course Code	CE/CZ4046			
Course Title	Intelligent Agents			
Pre-requisites	Study year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

Intelligent agents are a new paradigm for developing software applications and the focus of intense interest as a sub-field of Computer Science and Artificial Intelligence. Multi-agent systems arise when these agents co-exist, interact and cooperate with each other. Agents and multi-agent systems are being used in an increasingly wide variety of applications, such as personal assistants, e-commerce, traffic control, workflow and business process management systems, etc. This course will equip you with the skills and knowledge on the design and implementation of intelligent agents and multi-agent systems to solve large-scale, complex, and dynamic real-world problems.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

Describe the variety of connotations that agent-based computation implies and describe how the field fits into Artificial Intelligence and more broadly, Computer Science.

Identify the typical problems associated with intelligent agents and multi-agent systems.

Describe and debate the ways for solving problems related to intelligent agents and multi-agent systems.

Analyse real world and (possibly) new problems related to intelligent agents and multi-agent systems, and propose and evaluate possible mitigations.

Overview of Course Content

	Topics
1	**Introduction to Intelligent Agents** What is an agent; Principles of autonomy and agency; Views of the field from different aspects: Software engineering/simulation/AI; Relationship with AI/distributed systems/game theory/social science
2	**Deductive Reasoning Agents** Symbolic research agents; Planning systems; Planning agents
3	**Practical Reasoning Agents** Intentions and practical reasoning; Means-end reasoning; A Procedural reasoning system
4	**Reactive and Hybrid Architectures** Reactive vs hybrid; Brooks subsumption architecture; Limitations and hybrid architectures
5	**Introduction to Multi-Agent Systems and Applications** Definition of multi-agent systems; Applications of intelligent agents and multi-agent systems; Some demos
6	**Working Together** Benevolent agents; Cooperative distributed problem solving; Contract Net; Task sharing and result sharing; Coordination
7	**Multi-Agent Interaction** Utilities and preferences, Payoff matrices; Solution concepts, Game Theory; Nash equilibrium; Prisoners Dilemma
8	**Allocating Scarce Resources – Auctions** Definition of auctions; Categorisation of auctions; English auction; Dutch auction; First-price sealed bid auction; Vickrey auctions; Combinatorial auctions; Bidding languages; The VCG Mechanism; Some examples
9	**Making Group Decisions** Social Choice; Preference aggregation; Social Welfare; Voting procedures
10	**Forming Coalitions** Cooperative games; Computational and representational issues; Modular representations; Coalition games with goals; Coalition structure formation

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	60%	Individual
2. Course Project	40%	Individual/Team
Total	100%	

CE4123/CZ4123 – Big Data Management

Academic Year	AY2022-2023	**Semester**	2	
Instructor(s)	Luo Siqiang (siqiang.luo@ntu.edu.sg)			
Course Code	CE4123/CZ4123			
Course Title	Big Data Management			
Pre-requisites	CE/CZ4031 Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

We are in the "Big Data" era – an extremely large amount of data is created every day. The world of data management has dramatically changed in the "Big Data" era. This is primarily driven by multiple factors including cheaper storage costs, increasing availability of sensors, smart devices, social software, and availability of cloud computing infrastructure, and cheaper processing cost of large volumes of data due to dramatic advances in modern hardware (e.g., solid state disk, multicore CPUs, large memory). This seismic impact of big data has led to increasing demand in building scalable data infrastructures toward supporting real-world applications. This course aims to provide a broad understanding of big data and current technologies in managing and processing them. Key topics covered in this course include general principles of designing big data systems, distributed storage of big data, programming models in big data, big data analytics techniques, key-value stores, and big data analytics. Upon completion of this course, you will learn to evaluate issues associated with big data management and business data analytics, learn how the data is stored in a distributed file system and how queries and analytics run in parallel.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

5. Explain and describe the fundamental properties of big data, and basic operations of big data systems.
6. Discuss and explain the construction of big data systems based on different storage models and data models.
7. Analyse and describe the advantages of using different categories of data systems in certain real-world applications.
8. Describe and explain the data analytics procedures and techniques in big data applications industry.
9. Design and process big data using standard programming models and open APIs.

Overview of Course Content

	Topics
1	**Introduction to Big Data Management** The overall context of the big data era; Big data 5V's; Terminology: data volume, data velocity, data variety, data veracity, data value, data format, data structure; Histories and developments of big data systems
2	**Data Models and Query Languages** Relational models, schema, primary keys, foreign keys; Key-value models; Graph models; Query languages
3	**Designing Big Data Systems—General Principles** Concept of data system design; Storage hierarchy; Cache Mechanism; Cache-Conscious Design
4	**Architecture of Data Systems** Internals of Data Systems; logical plan, optimiser, physical plan; Query lifecycle
5	**Row Store and Column Store** Concept of row/column store; Advantages of row/column stores; Lazy tuple reconstruction; Vectorisation; Zone map; Query plans and cost analysis
6	**Distributed Systems and MapReduce** Distributed file system; Distributed computing; Programming models of MapReduce; Hadoop and Spark; Cloud computing
7	**NoSQL and Key-Value Stores** CAP theorem; Differences between Relational DB and NoSQL; Concept of key-value indexes; LSM-trees
8	**Big Data Analytics** Graph-based applications; Data mining in big data; Data warehousing

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quiz	30%	Individual
2. Project	30%	Team and Individual
3. Final Examination	40%	Individual
Total	100%	

MH1802 Calculus for the Sciences

This course aims to equip students with

- mathematical knowledge and analytical skills so that they are able to apply techniques of calculus (along with their existing mathematical skills) to solve scientific problems whenever applicable;
- mathematical reading skills so that they can read and understand related mathematical content in the basic and popular scientific and engineering literature; and
- mathematical communication skills so that they can effectively and rigorously present their mathematical ideas to mathematicians, scientists and engineers.

Content

Basics (BAS)
Types of numbers; Functions and Graphs; Commonly used functions and their graphs; Important algebraic, trigonometric, logarithmic and exponential identities; Basic Complex numbers.

Differential Calculus (DIF)
Limits; Differentiation; Techniques of Differentiation; Applications of Differentiation; Basic Partial derivatives.

Integral Calculus (INT)
Integration; Techniques of Integration; Calculus of Logarithmic, exponential and Inverse Trigonometric Functions; Applications of Integration;

Differential Equations (DE)
Basics; First Order Ordinary Differential Equations; Second Order Ordinary Differential Equations; Series, Sequences and Differential equations.

MH1812 Discrete Mathematics

Learning Objective

This Course introduces basic notions in discrete mathematics commonly used in mathematics and computer science.

Content
- counting, permutations and combinations, binomial theorem
- recurrence relations
- graphs, paths and circuits, isomorphisms
- trees, spanning trees
- graph algorithms (e.g., shortest path, maximum flow) and their computational complexity, big-O notation

MH2100 Calculus III

Learning Objective
This is the last course in the calculus sequence. In this course, multi-variable calculus is introduced.

Content
Parametric equations, polar coordinates. Vector-valued functions, calculus of vector-valued functions, solid analytic geometry. Functions of more than one variable, limits, continuity, partial derivatives, differentiability and total differential, chain rule, Implicit Function Theorem. Directional derivatives, gradients, Lagrange multipliers. Double integrals, area of a surface, triple integrals. Line integrals, Green's Theorem, surface integrals, Gauss' divergence theorem, Stokes' Theorem.

MH2500 Probability & Introduction to Statistics

Learning Objective
This course focuses on probability theory, with the view of probability distributions as models for phenomena with statistical regularity.

Content
Discrete distributions (binomial, hypergeometric and Poisson). Continuous distributions (normal, exponential) and densities. Random variables, expectation, independence, conditional probability. Introduction to the law of large numbers and the central limit theorem. Sampling distributions. Elementary statistical inference (confidence intervals and hypothesis tests).

MH2802 Linear Algebra for Scientists

This course aims to

1. Acquire a wider range of mathematical concepts related to vector spaces and linear algebra.
2. Develop a strong set of mathematical skills for upper level Science and Engineering courses.
3. Solve large systems of linear equations and related areas.
4. Develop thinking, reasoning, communication and modelling skills through a mathematical approach to problem-solving
5. Connect ideas within mathematics and apply mathematics in the contexts of Science and Engineering.
6. Experience and appreciate the rigour and abstraction in the discipline.

Content
1. Vector Algebra & Analytical Geometry
2. Calculus of Vectors
3. Linear Spaces
4. Matrices & Linear Transformations
5. Determinants
6. Eigenvalues and Eigenvectors
7. Applications of Linear Algebra to problems in Science and Engineering

MH3500 Statistics

Learning Objective
The purpose of this course is to introduce modern statistical concepts and procedures derived from a mathematical framework.

Content
Probability distributions of functions of random variables, the law of large numbers and the central limit theorem. Point and interval estimation, optimal estimation, maximum likelihood methods, more on tests of hypotheses, Neyman-Pearson lemma, likelihood ratio tests, large sample theory, Chi-square tests and contingency tables.

MH3510 Regression Analysis

Learning Objective
The object of study in this course is regression analysis – one of the most widely used statistical techniques.

Content
Simple and multiple linear regression, nonlinear regression, analysis of residuals and model selection. One-way and two-way factorial experiments, random and fixed effects models.

MH3511 Data Analysis with Computer

Learning Objective
This course introduces the use of statistical computer packages for performing data analysis.

Content
Data analysis process and collecting data, graphical and numerical methods for describing data, summarizing bivariate data, probability and population distribution, estimation and hypothesis testing using a single sample, comparing two population or treatments, analysis of categorical data and goodness-of-fit tests.

MH3701 Basic Optimization

Learning Objective
This is the first course in optimization and operations research. Basic methods and concepts are introduced.

Content
Introduction of optimization models: objective and constraints, convex sets and functions, polyhedron and extreme points. Introduction to LP: solving 2-variable LP via graphical methods; simplex method; dual LP and sensitivity analysis.
Karush-Kuhn-Tucker optimality conditions, optimal solution via optimality conditions. Duality theory. Network optimization: Shortest path, maximum flow, minimum cost flow, assignment problem, transportation problem, network simplex method.

MH4500 Time Series Analysis

Learning Objective
This course introduces time series models used in economics, engineering and finance.

Content
Trend fitting, autoregressive and moving average models, spectral analysis. Seasonality, forecasting and estimation. Use of computer package to analyze real data sets.

MH4501 Multivariate Analysis

Learning Objective
This course focuses on the standard methods of multivariate statistical analysis.

Content
Distribution theory: multivariate normal distribution, Hotelling's T2 and Wishart distributions, inference on the mean and covariance, principal components and canonical correlation, factor analysis, discrimination and classification.

MH4511 Sampling & Survey

Learning Objective
This course gives an introduction to sampling and the design of sample surveys.

Content
Ratio and regression estimators under simple random sampling, separate and combined estimators for stratified random sampling. Systematic sampling and its relationship with stratified and cluster sampling. Further aspects of stratified sampling, cluster sampling with clusters of unequal sizes. Subsampling; multi-stage sampling. Complex sample designs.

MH4513 Survival Analysis

Learning Objective
This course focuses on the standard methods of survival data analysis.

Content
Examples of survival data analysis, types of censoring, parametric survival distributions (exponential, Weibull, lognormal), nonparametric methods, Kaplan-Meier estimator, tests of hypotheses, graphical methods of survival distribution fitting, goodness of fit tests, parametric accellerated failure time model, Cox's proportional hazards model.

MH4515 Applied Bayesian Statistics

This course focuses on introducing conceptual, computational, and practical Bayesian approaches, with applications to various areas, such as social sciences, econometrics and health sciences.

Content
Bayesian statistics offer flexible techniques for analyzing data in which classical statistical methods may not be properly applied. This course provides a sound basis in Bayesian statistics by introducing conceptual, computational, and practical Bayesian approaches. It covers Bayes' theorem, common prior distributions, summarizing posterior distributions, comparison between Bayesian approaches and frequentist methods, Gibbs sampling, the Metropolis-Hastings algorithm, the evaluation of informative hypotheses, as well as Bayesian modelling using R.

MH4516 Applied Categorical Data Analysis

This course focuses on the statistical tools for analyzing categorical data with applications in medical and biological sciences.

Content
The course provides statistical methods and models for analysis of categorical data including proportions, count and binary/binomial type of data. The topics covered in this course include contingency tables, logistic, probit, Poisson regression and log-linear models, as well as analysis of ordered response categories. The implementation of methods using R or SAS and interpretation of results will also be emphasized.

MH4517 Data Applications in Natural Sciences

This course introduces topological data analysis (TDA) and discusses its applications in natural sciences.

Content
Review of algebraic concepts like: Simplicial complex, Vietoris-Rips complex, nerves, homology, Smith normal form, cohomology, etc. Recent new topological tools including: discrete Morse theory, Reeb graphs, Conley index, persistent homology, etc and their applications in natural sciences.

MH4518 Simulation Techniques in Finance

This course introduces a broad range of standard and specified simulation methods in finance with a focus on option pricing and risk management.

Content
Simulating sample paths. Pricing financial products and computing risk measures with the simulation techniques. Use of computer software to implement the Monte-Carlo simulation and its applications.

PH4410 Econophysics

Content
This course introduces statistical physics-inspired approaches to economics and finance. Review basic concepts in probability and statistics. Low- and high-frequency data in economics and finance. Gaussian and fat-tailed return distributions. Autocorrelation, memory, and nonstationarity in time series data. Cross correlations in financial markets. Random matrix theory. Correlation filtering and minimal spanning trees. Time series clustering. Agent-based models of financial markets. Stylized facts from simulation results.

CS4022 Social Media Mining

Students learn specialised techniques for mining text, including how to prepare textual data for analysis and carry out techniques including sentiment analysis and opinion mining. The emphasis is on using these tools in real world applications to answer research questions, gain insights for journalistic reporting, or generate information for clients. Strengths, weaknesses, and concerns such as privacy are also discussed throughout. Course Content Principles and concepts of text mining. Various text mining techniques: Pre-processing for Text Mining, Text Categorization, Document Clustering, Information Retrieval, Information Extraction, Opinion Mining and Sentiment Analysis, and Question Answering. Practical use of text mining to real world applications, such as Text Message Spam Detection and Sentiment Analysis Systems analyzing public opinion towards various subjects, such as electronic gadgets, movies, stocks, etc., using social media content.

CS4031 Media Planning & Strategies

The course introduces students to the quantitative aspects of media planning. Topics covered will include brand analysis, audience analysis, market segmentation, and media analysis. Case studies and real-life practices will be included in this class. During the first half of the semester, students will conduct a brand audit and develop and administer a survey to determine target audience media usage. The information from the brand audit and market survey will then be used to compile a strategic media plan. Strategies and recommendations will form the basis of the media plan. The course will be taught in an active learning fashion. It strives for a balanced coverage of theoretical and practical issues, industry norms and ideals, and facts and thoughts. The ultimate goal is for students to form their own perspectives, sharpen their strategic thinking, and advance their planning skills. To this end, students should become critical thinkers who move beyond a view of learning as information gathering to a view of learning as knowledg
All students are expected to be active and proactive in course activities.