ELEC3104
Digital Signal Processing

Course Outline – Semester 1, 2016

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Prof. E. Ambikairajah, Room G8, e.ambikairajah@unsw.edu.au

Tutorial-Lab Coordinator: Dr. Phu Le, Room EE206, ngoc.le@unsw.edu.au

Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. All course and tutorial-lab related emails should be directed to Dr. Phu Le in the first instance including consultations. Any email enquiry regarding the course should be made from your student email address with ELEC3104 in the subject line; otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Contact Hours

The course consists of 3 hours of lectures, and a 3-hour of integrated tutorial-lab each week. These face-to-face hours are supplemented by pre-recorded lectures and pre-recorded sample problem solutions, which can be downloaded online - http://eemedia.ee.unsw.edu.au/ELEC3104/index.htm

Lectures	Day	Time	Location	Name
	Tuesday	11:00-13:00	CLB 6	Prof. Ambikairajah & Dr. Phu Le
	Thursday	11:00-12:00	Colombo Th.	
Tutorial-Labs	Mon - Fri	Enrolled times	EE302	Lab Demonstrators
Consultations	Mon – Fri	Allocated time	Via Moodle	Lab Demonstrators

Context and Aims

Signal Processing is the process of measuring, manipulating or analysing information. Signals of interest include biomedical data, audio, still or moving images, radar, and even DNA. Filtering techniques can be crucial in revealing and interpreting information present in a signal. ELEC3104 Digital Signal Processing is an introductory signal processing course which takes students through the steps necessary to design and implement filters for a range of signals.

Aims

The course aims to equip students with:

- An understanding of the behaviour of a system, in terms of both its time domain and frequency domain representations.
- The skills to identify the correct type of filter required for a given problem and be able to demonstrate the design and implementation of a digital filter.
- The ability to explain the concept of aliasing and its effect on the design of practical systems.
- An understanding of multi-rate processing and multi-rate systems.

Indicative Lecture Schedule

The indicative lecture schedule is listed in the following table. The corresponding video for that lecture also included in the table. Please note that the chapter numbers in the lecture notes and the chapter numbers in the pre-recorded lectures do not coincide, so the table below indicates which chapter corresponds to which pre-recorded lecture.

Week	Topic
1-2	Chapter 1: Signals and Systems **(Chapter 1 video)** [LO: 1, 2, 3]
	Chapter 2: Digital Signal Processing Fundamentals **(Chapter 5 video (mainly 5A))** [LO: 1, 2, 3]
	Chapter 3: Discrete-Time Systems (**Chapter 2 video**) [LO: 1, 2, 3]
	Chapter 6: Discrete-Time Fourier Transform (Mainly DFT) (**Chapter 6 video**) [LO: 1, 2, 3, 5]
3-5	Chapter 4: Introduction to z-Transform (**Chapter 3 video**) [LO: 1, 2, 3]
	Chapter 5: Introduction to Digital Filters (**Chapter 5 video (mainly 5B and 5C**)) [LO: 1, 2, 3, 4]
6	Chapter 6: Discrete-Time Fourier Transform (**Chapter 6 video**) [LO: 1, 2, 3, 5]
7	Chapter 7: Analogue Filter Design (**Chapter 7 video**) [LO: 1, 2, 3, 4]
8-10	Chapter 8: Digital Filter Design (**Chapter 8 video**) [LO: 1, 2, 3, 4, 5]
11-12	Chapter 9: Multirate Digital Signal Processing (**Chapter 9 video**) [LO: 1, 2, 3, 4, 5, 7]
13	Revision
	Final Exam

Indicative Tutorial-Lab Schedule

Week	Suggested Lab work	Required Reading
1,2 & 3	Self-Study – MATLAB fundamentals and Complete MATLAB exercises by week 3	Online videos + Provided MATLAB Fundamental resources (refer Moodle)
4	Tutorial Lab	Chapters 1 – 3 + MATLAB Exercises A, B & C
5	**Tutorial Lab + Lab Quiz 1 (30mins)**	Chapters 1 – 3
6-7	Tutorial Labs	Chapters 1 – 5 + MATLAB Exercises A, B & C
8	**Tutorial Lab + Lab Quiz 2 (30mins)**	Chapters 1 – 5
9-10	Tutorial Labs	Chapters 1 – 8 + MATLAB Exercises A, B & C
11	**Tutorial Lab + Lab Quiz 3 (30mins)**	Chapters 1 – 8
12	Tutorial Lab + Mock Lab Exam (90mins)	Chapters 1 – 9 + MATLAB Exercises A, B & C
13	**Lab Exam (90mins)**	All Chapters

Note: Additional MATLAB resources including exercises will be made available on the course Moodle.

Assessment

Lab Quizzes (3 quizzes of 30 mins each)	21%
Lab Exam (90 mins + assessment time)	14%
Final Exam (3 hours)	65%

Course Details

Credits

This is a 6 UoC course and the expected workload is 10-12 hours per week throughout the 13 week semester.

Relationship to Other Courses

This is a 3rd year course in the School of Electrical Engineering and Telecommunications at the University of New South Wales. It is a core course for students following a BE (Electrical) or (Telecommunications) program and other combined degree programs, and an elective for Computer Engineering students.

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is ELEC2134, Circuits and Signals. It is essential that students are familiar with basic circuit theory, signal analysis and transform methods. It is further assumed that students are familiar with the MATLAB environment, and have good computer literacy.

Following Courses

The course is a pre-requisite for all professional electives in the Signal Processing group, including ELEC4621 Advanced Digital Signal Processing and ELEC4622 Multimedia Signal Processing

Learning outcomes

At the end of the course students should:

1. Be able to apply transform methods to the analysis of analogue and digital linear time-invariant systems
2. Develop the appropriate competency in converting between time and frequency domain representations of signals and systems
3. Understand the practical aspects of sampling and reconstruction and be able to select a suitable sampling rate for a given signal processing problem
4. Design and analyse analogue and digital filters for a given specification
5. Demonstrate an understanding of the use and applications of the Discrete Fourier transform
6. Have gained practical experience with the implementation of digital filters
7. Be able to implement a simple multi-rate system

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Syllabus

Processing and analysis of continuous (analogue) and discrete-time (digital) signals. Sampling continuous signals: the sampling theorem, reconstruction, aliasing and the z-transform. Analogue filters: Butterworth filters. Filter impulse and frequency responses, stability and digital oscillators. The Discrete Fourier Transform (DFT). Fundamentals of the design and realisation of finite impulse response (FIR) and infinite impulse response (IIR) digital filters. Linear and non-linear phase filters. Decimation, interpolation, multi-rate digital signal processing.

Teaching Strategies

Delivery Mode

This entire course will be delivered via live lectures and pre-recorded electronic whiteboard based lecture presentations. The live lectures will be supported by these pre-recorded lectures and pre-recorded sample problem solutions and you can watch these in your own time before the weekly lecture/discussion class. The advantages of the pre-recorded lectures are:

- You will be able to watch them at your own pace
- You can revisit the lecture content as many times as you like
- Things that you might miss in a normal live lecture (e.g. difficult mathematical concepts) are available on the video lectures and/or via the tutorial classes

Note that the laboratory material and the lecture material may not be entirely synchronised. The pre-recorded lectures on video provide you with an opportunity to cover material not yet covered in class. You should look through the laboratory notes to decide what material you need to look over.

Learning in this course

You are expected to attend all lectures, tutorial-labs, lab quizzes and lab exam in order to maximise learning. You must prepare well for your tutorial-lab classes. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial-Laboratory classes

The integrated tutorial-laboratory sessions are designed to help you develop your analytical skills and see how they are applicable in a practical context. You may divide your time between the analytical and the laboratory components as per your convenience but you should complete both within the allocated time. The analytical problems you will be given in these sessions will tend to be more involved than the sample problems in the recommended textbook and will also tend to involve more than one topic. **It is expected that you are able to solve the sample problems at the end of each chapter and the recommended text book prior to undertaking the tutorial-lab questions.**

The tutorial-laboratory schedule is deliberately designed to provide practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend this from Week 4 to Week 13. Laboratory attendance WILL be kept, and you MUST attend all tutorial-labs.

You are required to maintain a lab book for recording your observations. A lab book is an A4 size notebook. You have to purchase your own lab book from any stores.

After completing both the analytical questions given in the tutorial-lab sheet and the laboratory work (eg MATLAB exercises), you must present the lab book to your laboratory demonstrator to be signed off every week during your tutorial-lab session.

Tutorial-Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course for Session 1, 2016 must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, please meet the co-ordinator (Dr. Phu Le) to discuss the situation.

Pre-requisite to pass the course

A satisfactory performance (50% or greater) in **each** of the following, is a necessary requirement to pass this course:

- **Lab Exam**
- **Final Exam**

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through lab quizzes and the lab exam.

Lab Quizzes (3 quizzes of 30 mins each)	21%
Lab Exam (90 mins + assessment time)	14%
Final Exam (3 hours)	65%

Lab Quizzes (21%)

There will be 3 lab quizzes as outlined in the schedule above. Each will last 30mins and consists of an analytical question (with parts) and a MATLAB programming question. You will be assessed by the lab demonstrators and provided with feedback.

Lab Exam (14%)

The Laboratory Exam is an open book practical exam that includes MATLAB coding and analytical calculations. These exam questions will be based on what you have learned in your tutorial-lab classes and lectures. **You must pass the lab exams to pass the course.**

NOTE: **You** must attend all tutorial-lab classes **in order to be able to sit the lab exam**

Final Exam (65%)

There will be one final examination, testing your understanding of the principles and your analytical skills through a number of set problems. If for medical reasons, (note that a valid medical certificate must be provided to the university) you are unable to attend the final exam, you will be given another exam (either oral or written, at the discretion of the course convenor). **You must pass this final exam to pass the course.**

- The final exam will be 3 hours long
- The final exam consists of 5 questions (with many parts) and all of them must be answered

The final exam will cover all chapters covered in the semester

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Lab quizzes (21%)	✓	✓	✓	-	✓	✓	✓
Lab exam (14%)	✓	✓	✓	✓	✓	✓	✓
Final examination (65%)	✓	✓	✓	✓	✓	-	✓

Course Resources

Text books

Prescribed textbook

S. K. Mitra, Digital Signal Processing, McGraw-Hill, 2011. This book is available at the UNSW bookshop and also available as an ebook - https://create.mheducation.com/shop/#/catalog/details/?isbn=9781308454726

Reference books

- J. Proakis & D. Manolakis, Digital Signal Processing, Prentice-Hall, 2007.
- A. V. Oppenheim, R. W. Schafer, & P. Buck, Discrete-Time Signal Processing, Prentice-Hall, 2010.

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see http://www.lc.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://my.unsw.edu.au/student/atoz/ABC.html), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through**

myUNSW within 3 working days of the assessment, not to course or school staff. For more detail, consult https://my.unsw.edu.au/student/atoz/SpecialConsideration.html.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement (CATEI) Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings.

As a result of previous feedback obtained for this course (from 2014-2015) and in our efforts to provide a rich and meaningful learning experience, we have:

1. Integrated tutorials and laboratories to better reflect the practical implications of the theory.
2. Provided additional MATLAB resources including a series of videos
3. Assigned a lab demonstrator for each group of 18 students and have made them available outside of tutorial-lab hours for an additional hour of consultation each week and to be able to provide personalized feedback and support in the tutorial-labs.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Important Points

Please note the following:

- During your tutorial-labs, a lab demonstrator will be present and will be able to guide you in your laboratory-based learning.
- The lecture notes contain the course outline, problem sheets at the end of each chapter, a sample final exam paper and references.
- Soft copies of the above (lecture notes) will be made available on the course Moodle.
- MATLAB resources will be made available on the course Moodle.
- The pre-recorded lecture videos and tutorials can be downloaded from: http://eemedia.ee.unsw.edu.au/ELEC3104/index.htm For any problems with download etc, please contact, Dr. Phu Le on ngoc.le@unsw.edu.au
- Guidelines on learning that inform teaching at UNSW are available at www.guidelinesonlearning.unsw.edu.au

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as:

- Analytical skills, critical thinking and creative problem solving will be developed by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Self-assessment of independent and reflective learning is made available through a series of tutorials spanning the duration of the course together with the video-based learning material. The laboratory program fosters independent learning.
- Demonstration of the understanding of principles, and the effective use and communication of relevant information will be tested in depth, via the mid-semester examination and the final examination.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	✓
	PE1.5 Knowledge of engineering design practice	
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	
	PE3.4 Professional use and management of information	
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	

CATEI Results (S1, 2013 and S1 2015)

The university strongly encourages students to give their feedback at the conclusion of the course. Results from an online survey of ELEC3104 Digital Signal Processing in 2013 and 2015 are shown below.

Student Evaluation of a Course
ELEC3104 - Digital Signal Processing (S1, 2013)
165 enrolled; 89 Respondents (71 Male, 17 Female)

		A %	**D %**
Q1.	The aims of this course were clear to me	98	2
Q2.	I was given helpful feedback on how I was going in the course	90	10
Q3.	The course was challenging and interesting	97	3
Q4.	The course provided effective opportunities for active student participation in learning activities	94	6
Q5.	The course was effective for developing my thinking skills (e.g. critical analysis, problem solving).	98	2
Q6.	I was provided with clear information about the assessment requirements for this course.	92	8
Q7.	The assessment methods and tasks in this course were appropriate given the course aims	93	7
Q8.	The course advanced my ability for independent learning and critical analysis	96	4
Q9.	Good resources in laboratories and tutorials supported the learning process	91	9
Q10.	Overall, I was satisfied with the quality of this course	95	5

Mean Rating = 5.15
A - Agree; **D**- Disagree

Student Evaluation of a Course
ELEC3104 - Digital Signal Processing (S1, 2015)
206 enrolled; 75 Respondents (61 Male, 11 Female)

		A %	**D %**
Q1.	The aims of this course were clear to me	96	4
Q2.	I was given helpful feedback on how I was going in the course	92	8
Q3.	The course was challenging and interesting	94	6
Q4.	The course provided effective opportunities for active student participation in learning activities	91	9
Q5.	The course was effective for developing my thinking skills (e.g. critical analysis, problem solving).	94	6
Q6.	I was provided with clear information about the assessment requirements for this course.	86	14
Q7.	The assessment methods and tasks in this course were appropriate given the course aims	80	20
Q8.	The course advanced my ability for independent learning and critical analysis	92	8
Q9.	Good resources in laboratories and tutorials supported the learning process	88	12
Q10.	Overall, I was satisfied with the quality of this course	89	11

Mean Rating = 4.79

A - Agree; **D**- Disagree

Exam Results:

The following table shows the distribution of grades in ELEC3104 in 2013, 2014 and 2015

ELEC3104 marks distribution

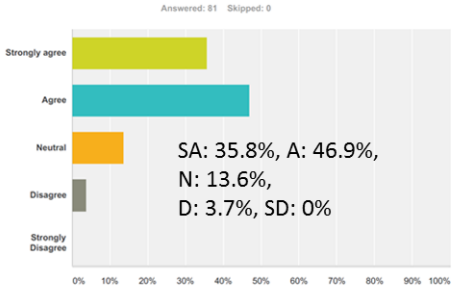
	S1 2013	**S1 2014**	**S1 2015**
HD	7%	8%	9%
D	15%	16%	17%
CR	28%	16%	15%
Pass	34%	44%	47%
Fail	16%	16%	12%
Total number of students	163	164	200

Students' Perception of Course Before/After Final Exam:
In S1 2015, ELEC3104 was selected for survey using the Survey_Monkey tool, specifically to understand students' attitudes to this course at two key points in the semester:

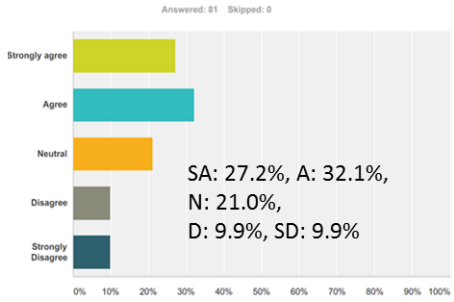
(i) immediately at the end of the lecture program (Stuvac) and

(ii) immediately after the final exam.

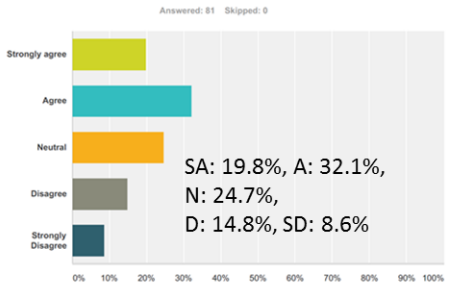
Before



Knowledge and Skill Base: The course enabled me to develop a comprehensive theory-based understanding of the fundamentals of digital signal processing, for example in signal sampling, digital filters and design, transform methods and multi-rate systems.



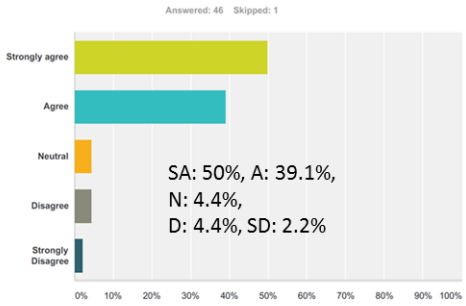
Engineering Application Ability: Through the laboratory program, the course has enabled me to apply engineering techniques, tools and resources, for example Spectral Analysis using FFT, Matlab, etc.

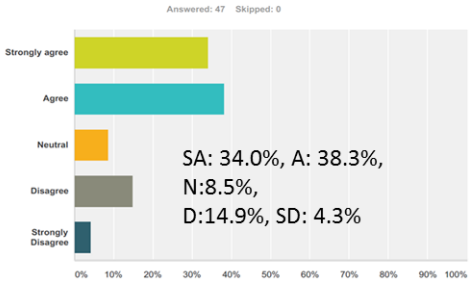


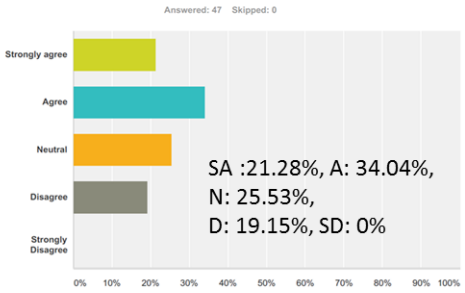
Professional and Personal Attributes: Through the laboratory program, tutorials, and application of knowledge gained from live and recorded lectures, I have enhanced my professional communication skills

Pre – Exam Survey
Respondents: 81

After







Post – Exam Survey
Respondents: 47

Alignment of Teaching Mode with UNSW 2025 Strategy (A2) : Scientia Educational Model

Strategy	Implementation in ELEC3104
Systematically integrating innovative teaching	Quality pre-produced lecture and laboratory recordings Solutions to tutorial problem sheets have been recorded
Blended and technology-enhanced teaching	Articulation between pre-recorded and live teaching
Personalised student experience	Demonstrator-led discussion groups (one per 18 students) allowing individual consultation
Building and supporting learning communities	Moodle discussion forum Demonstrator-led discussion groups (one per 18 students) allowing group learning and consultation
Flexible learning opportunities	Tutorial-labs provide students with support for tutorial (analytical) or laboratory (practical) learning, depending on their preference
Supporting and valuing teaching excellence	Peer-reviewed teaching in (i) live class, (ii) group discussion and (iii) tutorial-laboratory