

RESEARCH REPORTS

EXPLORING UNIVERSITY EDUCATION VARIATION: A MIXED-METHODS SURVEY OF AUSTRALIAN AND AOTEAROA NEW ZEALAND UNDERGRADUATE PARAMEDICAL ELECTROCARDIOGRAPHY CONTENT

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ABSTRACT

In Australia and Aotearoa New Zealand, statutory registration bodies define the capabilities expected of graduate paramedics but do not prescribe a minimum curriculum. Consequently, the extent to which universities differ in the content they teach is unknown.

Aim: To determine the depth of teaching and degree of overlap in electrocardiography content across university paramedicine programs.

Methods: A custom-designed mixed-methods survey comprising 377 electrocardiography topics and free-text questions was developed through a five-stage design and pretesting process. Fourteen of the eighteen eligible university programs participated (78%). Quantitative curriculum overlap was assessed using Simple Matching Coefficients, while qualitative responses underwent content analysis.

Results: Considerable variation was identified across university curricula. 66% of topics were taught by some universities and not by others, 30% were taught by all universities but to differing depths, and 4% were approached the same across all universities. Average university curriculum overlap was modest (52%, IQR 47%-60%). Qualitative responses reflected uncertainty regarding the appropriate breadth of undergraduate electrocardiography education, with participants describing it as "hard to know if we are teaching too much or not enough" and calling for a "standardized minimally accepted practice level."

Conclusion: There is a high level of heterogeneity in electrocardiography education in undergraduate paramedicine programs in Australia and Aotearoa New Zealand. This includes content with significant patient safety risks. Development of a standardized minimum curriculum would provide educators and employers with certainty about expected graduate electrocardiography capabilities and may improve patient safety.

INTRODUCTION

Across Australia and Aotearoa New Zealand, there are currently 18 active university programs accredited by Ahpra or Te Kaunihera to prepare graduates for initial paramedicine registration (Te Kaunihera Manapou, 2024; Paramedicine Board of Australia, 2026). To gain accreditation, universities must demonstrate that their programs enable graduates to meet the standards set by the Ahpra Paramedicine Board of Australia (PBA) or Te Kaunihera Paramedicine Council (Te Kaunihera Manapou, 2024; Paramedicine Board of Australia, 2026). These regulatory standards are intentionally high-level.

The PBA provides a list of “professional capabilities for registered paramedics”, which contains five broad domains, made up of twenty-one capabilities (Paramedicine Board of Australia, 2021). Domains capture broad groupings of capabilities such as “the paramedicine practitioner”, while the capabilities within domains capture similarly broad skills such as “understand the key concepts of the bodies of knowledge which are specifically relevant to paramedicine practice” (Paramedicine Board of Australia, 2021, p. 9). Universities must supply evidence that their programs support student attainment of these capabilities—for example, “understand the structure, function and pathophysiology of the human body” (Paramedicine Board of Australia, 2021). Te Kaunihera’s Standard of Cultural Safety and Clinical Competence for Paramedics mirrors these domains and capabilities closely, having been explicitly adapted from the PBA framework (Te Kaunihera Manapou, 2020). This outcomes-based structure is intentionally flexible and allows institutions to design curricula that suit their pedagogical philosophy and local workforce needs.

However, the mandated level of curricular detail stops here. It is at this intersection of capability-based regulation and curriculum design that a significant tension emerges. While the capabilities describe broadly what graduates must be able to do, they do not specify what content should be taught, or to what depth. No minimum curriculum is mandated by the PBA or Te Kaunihera. This omission may have important implications: in many health professions, clearly defined minimum curricula function as mechanisms to ensure baseline competence, enabling consistent assessment of essential knowledge and skills—and ultimately supporting safer and more equitable patient outcomes (Arja et al., 2024; World Health Organization, 2013).

Although this flexibility has advantages, it also raises an important question: does curriculum autonomy result in meaningful differences in the clinical knowledge possessed by graduates? Such variation has been raised previously. In 2000, Lendrum et al. stated: “the actual course content is variable... there is no published evidence that ambulance personnel are trained appropriately or that defines appropriate training” (Lendrum et al., 2000, p. 7). In a 2017 editorial, Boyle stated: “Even though university paramedic courses are currently accredited... there is still a variation in the standard of paramedic courses and paramedic graduates” (Boyle, 2017, p. 1). Perhaps more starkly, in 2024 an Australian undergraduate course coordinator stated: “I don’t know what the hell we’re supposed to be teaching them? I’m just not too sure what paramedics do” (Wilkinson-Stokes et al., 2024, p. 12).

Before policy responses can be considered, the extent of any variation must first be quantified. To date, no published literature has examined the extent of content variation

across accredited paramedicine programs. This study addresses that gap by providing an initial quantitative exploration of curriculum depth using electrocardiography as an exemplar. Three considerations informed the choice to use electrocardiography as the study topic.

Firstly, one motivating factor for this research was an unpublished sentinel event in which a graduate paramedic attempted to administer tenecteplase to a teenage patient with Brugada pattern (Coppola et al., 2021). Having never been taught the pattern (but now authorized to autonomously administer lysis by virtue of registration as a paramedic), they mistook it for septal ST elevation and misdiagnosed an acute left anterior descending occlusion. A similar incident of ECG misdiagnosis in the UK resulted in the death of a 29-year-old woman. This led to a coroner's investigation (Lees, 2023) and in turn to an ongoing investigation into paramedic electrocardiograph abilities (Health Services Safety Investigations Body, 2024). This has so far identified at least three preventable deaths from paramedic misinterpretation of electrocardiographs (Health Services Safety Investigations Body, 2025). However, the rationale for this study extends beyond individual incidents and reflects broader questions regarding consistency of educational preparation under capability-based accreditation models.

Secondly, electrocardiography is considered a fundamental skill for paramedics, having been described as "critical" (Mobrad, 2020, p. 824), "important" (Williams et al., 2008, p. 526), "a priority" (Wyld et al., 2023, p. 496) and "an essential competency in modern paramedicine" (Sibley et al., 2021, p. 1). Accordingly, ECG interpretation is taught universally across programs, making it a suitable comparator through which to examine program-level variation.

Finally, ECG interpretation is a conceptually complex area for education (Bishop and Meadley, 2025), and even medical degrees struggle to cover it comprehensively at undergraduate level (Viljoen et al., 2020). Consequently, educators must make decisions about which specific ECG concepts to include, emphasize, or omit. This natural process of pedagogical prioritization creates an ideal environment for exploring whether the capability-based accreditation model leads to meaningful differences in curricular scope.

This study therefore uses electrocardiography as a case study to interrogate the broader challenge inherent in capability-based accreditation: whether high-level regulatory standards, in the absence of a defined minimum curriculum, may inadvertently permit unsafe variation in graduate capabilities. By mapping the content and depth of ECG instruction across all accredited paramedicine programs in Australia and Aotearoa New Zealand, this research aims to identify whether meaningful differences exist and whether these differences warrant policy or curricular reconsideration. The findings will be of relevance to regulators, educators, and employers, as the paramedicine sector seeks to balance flexibility and public protection within a maturing professional landscape.

AIM

This project aims to explore variation in the teaching of electrocardiography within Australian and Aotearoa New Zealand entry-to-practice paramedicine programs. Specifically, it seeks to answer the questions:

- What is the proportion of predefined electrocardiography topics taught across different programs?
- To what depth are topics taught across different programs?
- What is the degree of overlap and variation in content across different programs?
- What are the opinions of lecturers on tertiary content variability?

METHODS

This study uses a concurrent, mixed-methods design (quantitative focus, with an embedded qualitative component). As no validated instrument exists to quantify the breadth and depth of electrocardiography curricula across undergraduate paramedicine programs, a bespoke survey was developed specifically for this study. Questions were primarily multiple-choice, with nested free-text boxes for open-ended participant commentary and unanticipated responses (Story & Tait, 2019). The survey was designed in five stages between February and November 2024 using established methods (De Vaus, 2013; O’Cathain & Thomas, 2004; Peterson, 2000; Story et al., 2011; Story & Tait, 2019; Tait & Voepel-Lewis, 2015).

Firstly, existing undergraduate and postgraduate paramedicine university course materials across three institutions were combined to develop a comprehensive three-tier taxonomy of electrocardiography content that organized content as 10 “subjects” (e.g. “12/15/16 lead analysis”), 68 “groups” (e.g. “Imposters/mimics”) and 377 “topics” (e.g. “Brugada Sign Type 1”). This taxonomy formed the skeleton of the quantitative data collection and is provided in the Appendix. To reduce the likelihood of acquiescence bias (i.e. breaking the habit of participants selecting that all topics are taught by forcing them to acknowledge some topics are not), content historically included in postgraduate courses (taught at the critical care paramedic level) was explicitly included. This was also anticipated to assist in distinguishing where universities were differentiating; as there is no minimum undergraduate content some universities may be including content historically taught to postgraduates as part of the undergraduate degree, which this approach sought to capture.

Secondly, an initial survey and set of instructions were developed using these as the content by one researcher (MWS). The survey was designed to include exhaustive and mutually exclusive closed-ended questions, with free-text fields regularly added to allow participants to provide unanticipated responses (Tait & Voepel-Lewis, 2015). Topics were able to be categorized into one of five categories to capture if they were taught, and if so to what depth; this categorization is outlined in Table 1. To maximize consistency in interpretation, each category was accompanied by a standardized written definition and illustrative examples within the survey. Participants were instructed to base responses on the 2024 teaching year after reviewing historical teaching materials where necessary, and the wording of all categories was refined through iterative expert piloting and pretesting with members of the target population. The categories were intentionally hierarchical, representing increasing educational depth from “Not taught” through to “Assessed”, thereby providing mutually exclusive levels of curriculum exposure.

Thirdly, the survey materials were pretested on the remaining research team (SM, NB). This included reviewing the order and flow of questions, ambiguity, and time to complete. Fourthly, three content experts piloted the survey: a critical care paramedic and educator, a second critical care paramedic, and a community paramedic with postgrad-

uate qualifications in urgent-primary care and experience as an educator. Fifthly, the survey materials were pretested on 11% of the target population (Story & Tait, 2019); two university lecturers who recently taught electrocardiography to undergraduates. The five content experts and recent participants were interviewed either via telephone or email post-survey, with the opportunity to provide specific feedback on any aspect of the survey (feedback summarized in the Appendix). Pretesting suggested high face validity and content validity. From this, the results of pretesting were discussed among the research team, and the final design was confirmed. Given that the participants were university lecturers, common acronyms were used where appropriate.

Categorization		Definition Provided to Participants
Taught	Assessed	“Assessed” means that the topic is considered key for undergraduate paramedics and, as well as being taught in theory and practiced, appears on formal assessment, including on examinations, assignments, or OSCEs.
		Many universities have statements akin to “all content within the learning material is assessable”. We encourage you to review which of these topics were historically taught as theory, practiced, or assessed during the 2024 teaching year.
	Practiced	“Practiced” means that a topic is discussed in theory, and additionally practically applied by students themselves in any of tutorials, simulations, labs, or hands-on skills classes.
		For example, a student may be asked to assess an ECG in a non-exam environment like a tutorial, or the topic may be part of class discussions or group work.
	Theory only	“Theory only” means that the topic appears in teaching materials, such as lecture slides, but students do not practice applying this in a classroom setting.
		For example, students may be expected to be familiar with a concept but aren’t expected to practice applying it in the classroom.
Not taught	Not taught	“Not taught” means that the topic is not formally discussed in any teaching materials.
Null response	Unsure / Taught elsewhere	“Unsure / taught elsewhere” means that the topic is taught in a separate unit by other staff, and you are not sure if it is taught or the depth it is taught to.
		This functioned as a null response and was excluded from analysis.

Table 1. Categories of topics available to participants.

Note. ECG: electrocardiograph; OSCE: objective structured clinical examination.

Finally, at the conclusion of the survey, participants were provided with an additional free text box and the question “We are not yet sure if there are any meaningful variations across electrocardiography undergraduate course content. If there are or aren’t, what are your thoughts on this topic?” The full survey remains available online to ensure reproducibility (https://q.surveys.unimelb.edu.au/jfe/form/SV_9GCQ3O5XT5aj0Mu). Transcribed free-text responses were independently coded by all three researchers using an inductive approach; emergent codes were identified iteratively, and disagreements were resolved through discussion until consensus was reached. Triangulation was used to integrate and compare findings from the quantitative and qualitative components of the study, enhancing the completeness and credibility of research findings (Mertens and Hesse-Biber, 2012). This study is reported in accordance with the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) (Sharma et al., 2021).

SURVEY RECRUITMENT

All 18 universities in Australia and Aotearoa New Zealand that provide active Bachelor level paramedicine programs were invited to participate (Te Kaunihera Manapou, 2024; Paramedicine Board of Australia, 2026). The sampling frame therefore overlapped entirely with the target population. Two additional institutions provide only graduate diploma

programs; these have been excluded due to uncertainty about the expected prior knowledge of students, and consequently that these are a distinct population and inclusion would confound results.

Prior to the design of the study, in January 2024 all 18 target universities were directly contacted via telephone, and a relevant lecturer was spoken to. This allowed *prima facie* willingness to participate to be gauged, to determine if the study was feasible, and to minimize the risk of low response rates leading to survey responder bias. After completing the survey design and ethical approval, between January and April 2025 participants were re-contacted and formally recruited. Where electrocardiographs were taught across multiple units, the unit coordinator of the final unit was recruited (as it was considered that they would have the best overall view of the cumulative content taught across the degree). Each unit coordinator was video conferenced or teleconferenced, and the project was discussed. Those who proceeded to participate signed a written Consent Form before being provided with the survey. As the sampling frame comprised all eligible universities, the principal remaining source of selection bias was voluntary non-participation rather than sampling error.

ANALYSIS

Prior to analysis, the validity of the results was considered based on the response rate, representative sampling, and non-responder bias, with a response rate of >40% considered acceptable (Story et al., 2011; Story & Tait, 2019). The data corpus was imported into R. Consistent with the study aims, descriptive statistics were used to quantify curriculum coverage, pairwise similarity coefficients were used to measure curriculum overlap between institutions, and qualitative content analysis was used to identify common perspectives expressed in free-text responses. Each of the 10 subjects, 68 groups, and 377 topics was assessed by the frequency of different categories, along with overall institution percentages and stacked bar charts for visualization. Each university was then compared against the other universities in a pairwise matrix of 91 comparisons of the 377 topics (for a total of 34,307 possible comparisons), with Simple Matching Coefficients (SMC) used to index the similarity. R code is provided in the Appendix.

Because the primary aim was to determine whether institutions approached individual topics identically rather than measure the magnitude of disagreement, a categorical similarity measure was selected. The SMC is a similarity measure for categorical data (Sokal and Michener, 1958; Warrens, 2008) that permits intuitive interpretation of overlap between programs. Unlike distance measures that weigh disagreement differently, SMC was selected because the research question concerned exact agreement between institutions (Warrens, 2008). While similar previous research used the Jaccard coefficient (Were et al., 2021), we intentionally differed and used the Simple Matching Coefficient (SMC). This was because agreement between two universities in not teaching a topic was considered a meaningful similarity in curricular approach, particularly given that the survey included postgraduate-level content. Unlike the SMC, the Jaccard coefficient excludes joint absences from the calculation and would therefore not capture this. The SMC calculation is shown in Figure 1.

Practically, the Simple Matching Coefficient was calculated by excluding comparisons containing null responses, coding each topic comparison between two universities bi-

$$\text{Simple Matching Coefficient} = \frac{\text{Number of matching attributes}}{\text{Total number of attributes}}$$

Figure 1. SMC calculation.

narilly (1 for identical responses and 0 for different responses), and dividing the number of identical responses by the total number of valid comparisons. This produced a coefficient ranging from 0 (completely dissimilar) to 1 (completely identical). The distribution of the 91 pairwise coefficients was then examined and visualized using a heatmap and violin plot with a nested boxplot. SMCs are an index, however here they have been presented as percentages to aid in reader interpretation.

For the qualitative question “What are the opinions of lecturers on variation in tertiary subject content?”, content analysis was performed by three researchers (MWS, SM, NB) to systematically code and categorize open-ended survey responses to identify patterns and themes (Hsieh and Shannon, 2005).

ETHICS

Ethical approval was granted by the University of the Sunshine Coast Human Research Ethics Committee (approval A242245). The main ethical risk considered during design was the reputational risk from data being construed to suggest that some universities are more thorough, or perceived to have more comprehensive teaching, than others. To minimize this risk, which universities participated is not stated and responses were anonymized at the point of collection.

RESULTS

Of the 18 universities, 17 (94%) consented to participate. Of these, 14 (78% of the target population, 82% of participants) returned complete surveys, a high response rate that is suitably representative of the target population. The low dropout rate (18%) suggests minimal risk of attrition bias. “Unsure / Taught Elsewhere” responses and blanks were treated as null data and omitted from all calculations. These comprised 4.5% of all responses (n=238 of 5,278 topic-level responses) and less than 13% of responses for any of the 10 subjects (average 5%, range 0-12%), suggesting minimal impact on the reliability of results.

Two atypical response patterns were observed. University 7 reported that nearly all electrocardiography topics were assessed, whereas University 11 reported that no electrocardiography topics were assessed. University 11's responses were supported by contemporaneous free-text comments explaining that electrocardiography was intentionally not assessed within that university, thereby providing contextual corroboration for the unusual response pattern. In contrast, no equivalent explanatory information was available for University 7. Because the survey was anonymous, it was not possible to seek clarification or independently verify the unusually high proportion of assessed topics. Consequently, University 7 responses were retained in the primary analysis (as there was no objective basis for exclusion), with a sensitivity analysis excluding the results undertaken. This sensitivity analysis produced no meaningful change in the findings, supporting the robustness of the results.

QUANTITATIVE RESULTS

Of the 377 topics surveyed no topic was taught, and taught at the same depth, by all responding universities. 15 (4.0%) were not taught at all responding universities. A further 114 topics (30.2%) were taught by all responding universities but to differing depths, while 248 (65.8%) were taught by some universities and not taught by others. Overall findings are summarized in stacked bar graph form in Figure 2.

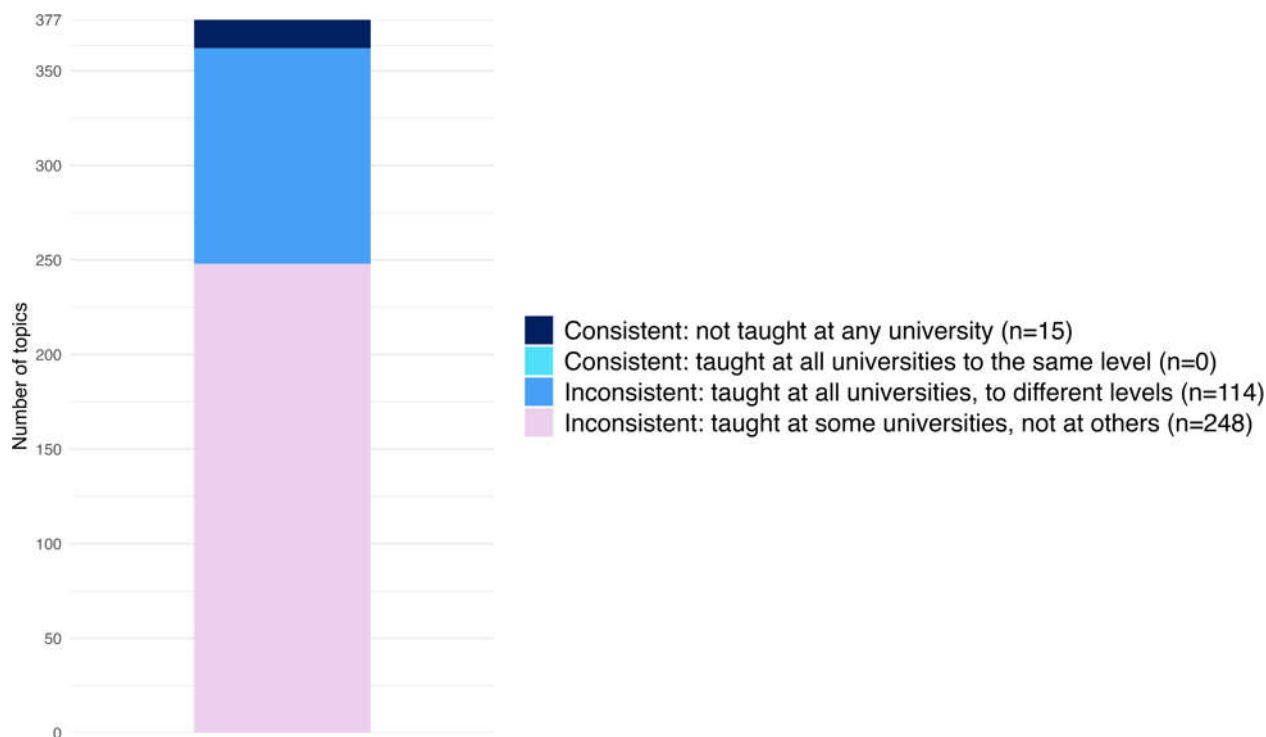


Figure 2. Consistency of topics across all 14 institutions.

Table 2 provides an example of responses below and illustrates how numerical results were derived from categorical responses. It shows the responses for the “equivalents” group—electrocardiographic patterns that may indicate occlusive infarction amenable to reperfusion but that present differently from basic ST-segment elevation (Asatryan et al., 2019). Listed below the responses for each university are the numerical and percentage results, with the percentages excluding null responses. Full results are available in the dataset published online (https://figshare.com/articles/dataset/Dataset_xlsx/29387729).

Each university pair’s topic coverage was compared to generate a matrix of SMCs, provided as a pairwise matrix in Table 3 and visualized as a heatmap in Figure 3.

Across the 91 pairwise university comparisons, the mean SMC was 52%, with a median of 54%, and an interquartile range of 47%–60%. This means that any two universities, on average, teach approximately half of their content the same. The minimum, between Universities 7 and 11, was just 1% (near perfect dissimilarity): across all 377 topics, these two institutions had the same approach to just 3 topics. The maximum, between Universities 7 and 14, was 90%: these two institutions had the same approach to 239 topics. However, as discussed, University 7 may be an incorrect response. If University 7 is omitted, the

Topic	Example of Responses, Using the ACOMI-STEMI Equivalents Topic								
Sub-Topic	Equivalents Generally	Reciprocal Changes Only Visible - Posterior or Isolated RVMI	LMCAO	New Left Bundle	New Left Bundle - Smith Modified Sgarbossa	Wellens - Type A	Wellens - Type B	de Winter	Aslanger
University 1	Theory only	Theory only	Theory only	Theory only	Not taught	Theory only	Not taught	Theory only	Not taught
University 2	Practiced	Practiced	Unsure / taught elsewhere	Practiced	Assessed	Practiced	Practiced	Unsure / taught elsewhere	Unsure / taught elsewhere
University 3	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught
University 4	Theory only	Assessed	Not taught	Not taught	Not taught	Assessed	Assessed	Assessed	Not taught
University 5	Assessed	Theory only	Theory only	Theory only	Theory only	Theory only	Theory only	Theory only	Theory only
University 6	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught	Not taught
University 7	Assessed	Assessed	Assessed	Assessed	Assessed	Unsure / taught elsewhere	Unsure / taught elsewhere	Unsure / taught elsewhere	Unsure / taught elsewhere
University 8	Not taught	Assessed	Theory only	Not taught	Assessed	Not taught	Not taught	Not taught	Not taught
University 9	Practiced	Practiced	Not taught	Assessed	Practiced	Practiced	Practiced	Practiced	Not taught
University 10	Assessed	Assessed	Assessed	Assessed	Theory only	Theory only	Theory only	Assessed	Theory only
University 11	Theory only	Not taught	Not taught	Theory only	Not taught	Theory only	Not taught	Not taught	Not taught
University 12	Assessed	Theory only	Theory only	Theory only	Theory only	Assessed	Theory only	Theory only	Not taught
University 13	Practiced	Not taught	Practiced	Practiced	Practiced	Practiced	Practiced	Practiced	Not taught
University 14	Assessed	Assessed	Assessed	Assessed	Assessed	Theory only	Theory only	Theory only	Unsure / taught elsewhere
Summaries (note: summary percentages only include A/P/T/NT responses; U responses are excluded)									
Assessed	5 (36%)	5 (36%)	3 (23%)	4 (29%)	4 (29%)	2 (15%)	1 (8%)	2 (17%)	0 (0%)
Practiced	3 (21%)	2 (14%)	1 (8%)	2 (14%)	2 (14%)	3 (23%)	3 (23%)	2 (17%)	0 (0%)
Theory only	3 (21%)	3 (21%)	4 (31%)	4 (29%)	3 (21%)	5 (38%)	4 (31%)	4 (33%)	2 (18%)
Not taught	3 (21%)	4 (29%)	5 (38%)	4 (29%)	5 (36%)	3 (23%)	5 (38%)	4 (33%)	9 (82%)
Unsure	0 (0%)	0 (0%)	1 (7%)	0 (0%)	0 (0%)	1 (7%)	1 (7%)	2 (14%)	3 (21%)

Table 2. Education of occlusive myocardial infarction equivalent patterns.

	2	3	4	5	6	7	8	9	10	11	12	13	14
1	42%	51%	59%	47%	57%	37%	51%	47%	42%	41%	52%	54%	44%
2		59%	54%	67%	48%	69%	63%	51%	61%	23%	64%	55%	68%
3			59%	60%	58%	60%	66%	55%	56%	29%	59%	55%	56%
4				55%	57%	54%	61%	51%	54%	28%	50%	51%	54%
5					50%	68%	64%	49%	62%	28%	71%	54%	67%
6						40%	51%	53%	42%	38%	49%	56%	46%
7							71%	42%	81%	1%	70%	44%	90%
8								49%	59%	27%	63%	50%	67%
9									47%	37%	48%	53%	47%
10										20%	67%	49%	74%
11											27%	33%	15%
12												54%	70%
13													47%

Table 3. Pairwise matrix of simple matching coefficients.

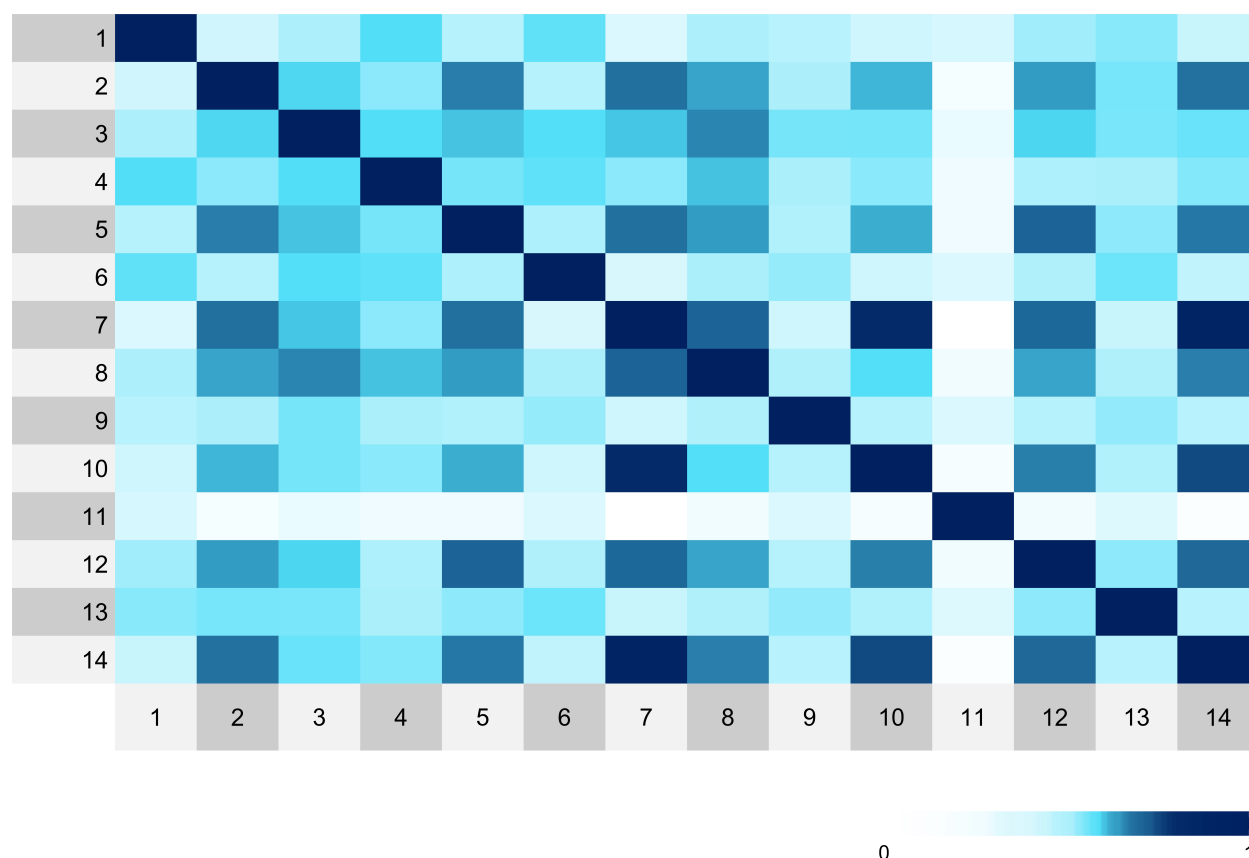


Figure 3. Heatmap of simple matching coefficients.

mean drops to 51%, with a median of 53%, an interquartile range of 47%–59%, and a range of 15%–74%; omitting University 7 has no meaningful impact on overall metrics. The spread of coefficients is provided in Figure 4.

Figure 5 illustrates the relative depth of teaching at each university. This graph omits null responses, therefore providing totals below the 377 topics surveyed. This graph also illustrates the differing approaches to education across institutions: while several are assessment-heavy, at least one was confirmed to use no assessment at all.

If University 7's results are excluded, the highest possible level of conflict—in which at least one university does not teach a topic at all, while at least one other university included it in their assessments—is present for 55% of topics ($n=208$). These 208 topics are visible in the online dataset.

QUALITATIVE RESULTS

Of the 14 responses received, 5 (36%) provided additional commentary. Participants noted uncertainty and expressed concern about what they should be teaching, stating: “At the moment, it’s hard to know if we are teaching too much or not enough” (University 1) and “We feel as if there are significant variations across tertiary institutions” (University 5).

The need to distinguish what curriculum should be included across different capability levels was raised: “We also need differentiations of skill levels. i.e., all paramedics can obtain and assess 12 Lead ECG for dysrhythmias and ACS. All ‘intensive care/equiva-

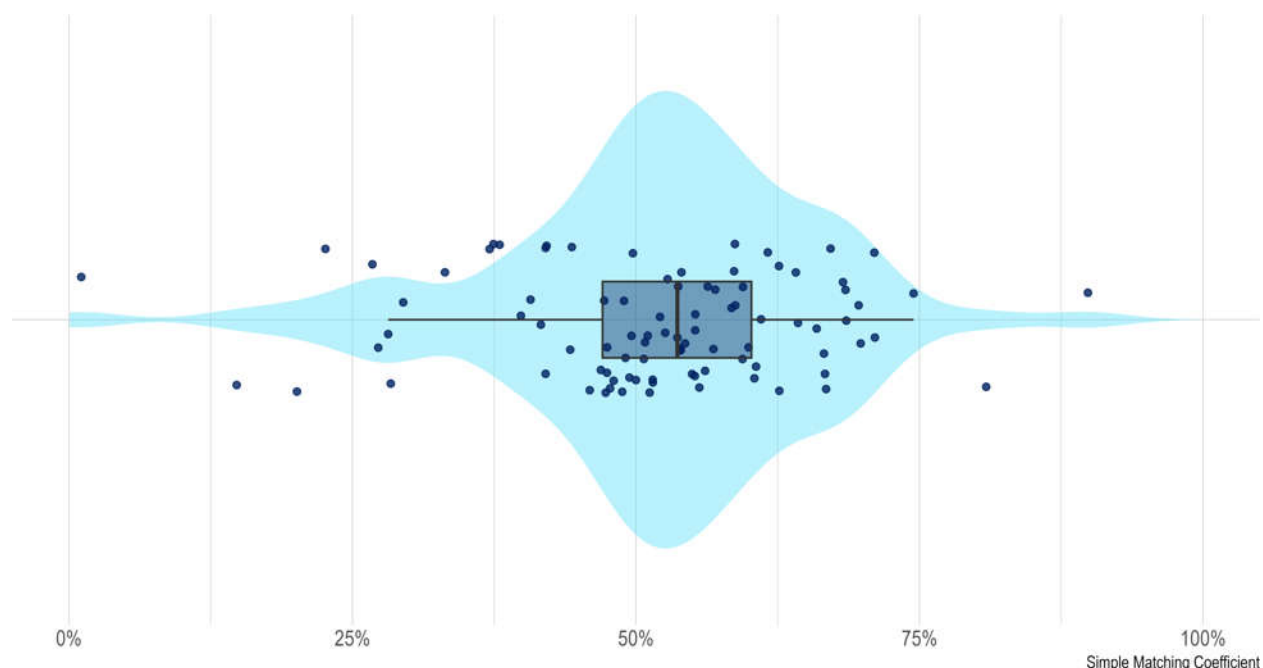


Figure 4. Violin Plot with Nested Boxplot of Simple Matching Coefficients.

lent’ paramedics can . . . whatever the next level is decided to be” (University 2) and “Just because some of the topics have been taught to that level in this course, it does not necessarily reflect where the standard should be at an undergraduate level” (University 14).

One university stated they explicitly include more complex content due to their higher student admission scores: “Our student entry requirements are very high, which means we can cover more content with our students” (University 10).

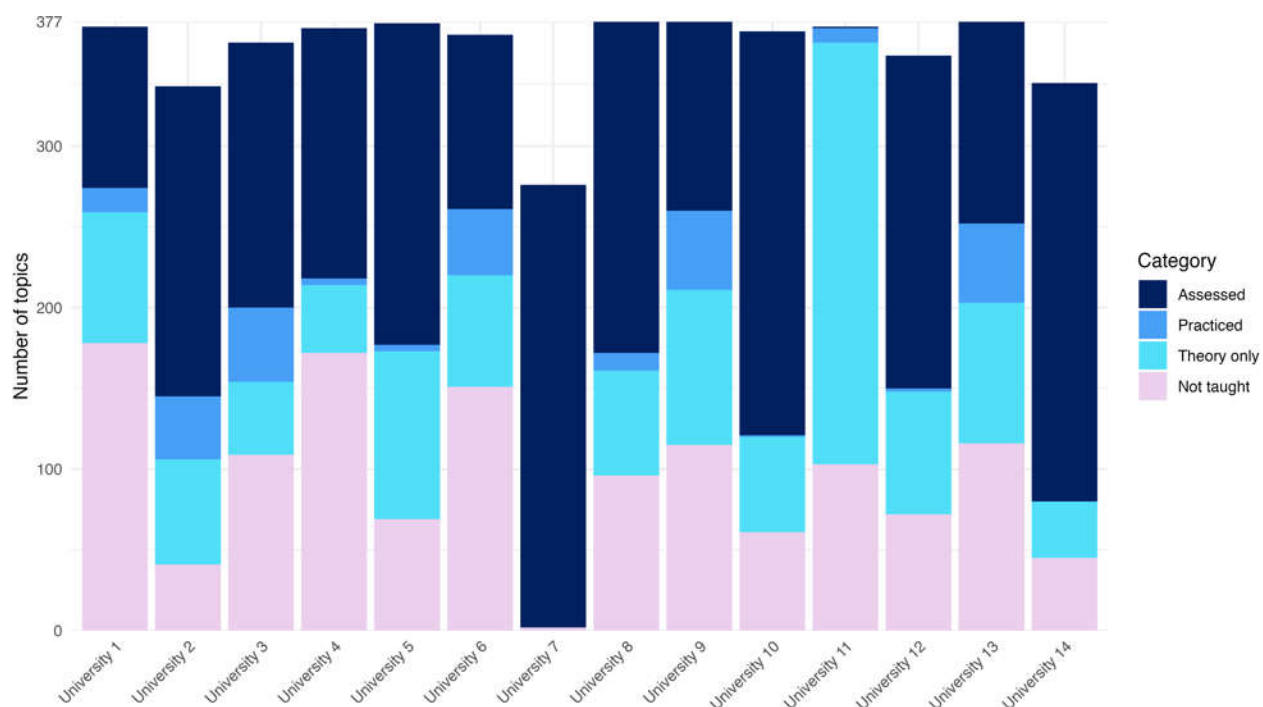


Figure 5. Number of topics in each category by University.

Finally, lack of regulatory guidance was noted: “It would be great to have literature recommending a certain level of ECG knowledge required for undergraduate students” (University 1) and “As with many areas of paramedicine, the lack of guidance from Ahpra will make this a challenge to address. There should be a standardized minimally accepted practice level for ECGs in paramedicine in Australia” (University 2).

TRIANGULATION

The nested qualitative responses provided some explanation for the quantitative findings. The quantitative data showed a very high level of heterogeneity in course content, with the mean similarity across topics being just 52%. The qualitative response echoed this: participants were unsure of what topics they should be teaching undergraduates. The qualitative also linked differing entry requirements with differing student abilities, suggesting courses with higher entry scores intentionally include content beyond what they consider the “minimum standard” to practice as a registered paramedic. This “minimum standard”, however, does not appear well-defined: across all institutions, there were just 15 of 377 sub-topics taught to the same depth. Cumulatively, these results suggest that undergraduate paramedicine electrocardiography education in Australia and Aotearoa New Zealand is highly inconsistent, and that a standardized minimum curriculum is sought by educators.

DISCUSSION

To our knowledge, no previous published study has quantified any potential inconsistency across Australian and Aotearoa New Zealand undergraduate paramedicine university program content. These findings provide the first empirical evidence to date of inconsistency in the field of electrocardiography education. The results of this paper demonstrate a high level of inconsistency in topics taught—with an average of 52% similarity and, in one instance, a near-perfect dissimilarity of 1%. Most concerning, this heterogeneity extends to topics with direct life-threatening patient safety implications. For example, the Smith-modified Sgarbossa criteria for identifying a heart attack were part of final assessment in four universities but not taught at all in five others.

However, this research does not explain why variation is present. Speculatively, this phenomenon likely emerged as each university currently develops its course topics independently, with regulatory standards for courses being high-level and lacking specificity regarding individual topics. Teaching materials are rarely open access, being sometimes considered the intellectual property of the university and sometimes the intellectual property of the creating staff (Jamali, 2024). This legal barrier inhibits comparison across facilities by staff, potential graduate employers, or students, leading to uncertainty as to the topics covered. This appears to be compounded by an uncertain professional identity within the discipline as paramedicine moves out of its traditional ambulance-based roles (Corman et al., 2025; Eastwood et al., 2023).

Similarly, educational requirements provided to universities by regulators are reasonably abstract—for example, that graduates can “understand the structure, function, and pathophysiology of the human body” (Paramedicine Board of Australia, 2021), providing minimal practical guidance for educators. The standards of Ahpra and Te Kaunihera do not, for example, specify that courses are required to teach any cardiology. More specifically, there is no written requirement that undergraduate paramedicine programs

teach electrocardiography, nor any mandated list of ECG topics such as interpretation of 12/15/16-lead electrocardiographs, or the detail that may in turn lie beneath these, such as identification of occlusion equivalents such as de Winter (de Winter et al., 2008), Aslanger (Aslanger et al., 2020), or Wellens (Rhinehardt et al., 2002). This high-level approach has allowed circumstances to emerge where one university does not assess knowledge of electrocardiographs, but where all graduates may be registered to practice autonomously—including providing interventions based on ECG interpretation—without their knowledge for safe practice being confirmed.

Participants frequently described uncertainty regarding whether they were teaching too much or too little. This uncertainty is an important finding. Rather than reflecting disagreement about educational philosophy, in the context of this study it suggests the absence of an agreed benchmark against which curricula can be calibrated. In professions with defined minimum curricula, educators can compare their teaching against nationally accepted expectations. In contrast, the absence of such benchmarks may leave curriculum decisions dependent on educator expertise and historical practice. Reasonable educators may therefore arrive at markedly different curricular decisions while remaining fully compliant with accreditation standards.

Course benchmarking, a requirement under the Higher Education Standards Framework in Australia, may offset these risks by providing some basic level of consistency across different institutional courses (Tertiary Education Quality and Standards Agency, 2024; Department of Education, Skills and Employment, 2021). Course benchmarking compares course design and student performance across institutions; this usually includes comparison of admission criteria, assessment tasks, student work samples, and assessment criteria (Tertiary Education Quality and Standards Agency, 2024). However, it does not routinely include topic comparisons or the depth to which these topics are taught. A second mechanism that may provide some consistency is the movement of academics between institutions; however, this occurs on an ad hoc basis and cannot be considered a reliable means of establishing standards.

Although electrocardiography was selected as the exemplar because of its clinical importance and conceptual complexity, the findings have implications beyond ECG education. Any knowledge domain lacking a prescribed minimum curriculum is susceptible to similar variation. Consequently, the results raise broader questions regarding whether capability-based accreditation alone is sufficient to ensure consistent graduate preparation across the profession.

However, there are valid competing arguments against establishing a minimum curriculum to address this. Firstly, regulators may additionally be concerned that establishing standards may inadvertently constrain the progression of the profession into novel areas if it were treated as a ceiling rather than a baseline. Additionally, the argument for some baseline standards for electrocardiograph content in this paper is built on the assumption that all graduate paramedics should be taught electrocardiographs. Despite the earlier statements that it is often considered fundamental for clinical practice, no definitive source states that a graduate must be competent in electrocardiography to be a paramedic. Is knowledge of electrocardiographs required to become a “paramedic”? The current regulatory position is: no.

Secondly, the purpose of a university is not to simply teach a memorizable list of content or skills—an approach more reflective of vocational education (Blake et al., 2003; Moore & Morton, 2017). Universities instead focus on theory underpinning practice (Blake et al., 2003). However, over the previous decades, there has been an increasing movement within the tertiary education sector to produce “job-ready” graduates with a practical and relevant skill set to employment, including incentives by the Australian Government (notwithstanding the Australian University Accords recommendation to step back from this approach) (Blake et al., 2003; Daly & Lewis, 2020; Tomlinson, 2012).

Despite these counterarguments, having no minimum educational standards for safe practice has undeniable safety risks when paramedics are making autonomous ECG interpretations, as illustrated by the three deaths reported in the UK. The 2025 UK report explicitly identified confusion regarding the expected knowledge of paramedics and stated that there is no formal requirement for whether ECGs should be taught, how they should be taught, or to what standard (Health Services Safety Investigations Body, 2025).

While the UK’s industry college has previously provided some brief, non-binding guidance for paramedics (College of Paramedics, 2024), no such statement exists within Australian or Aotearoa New Zealand paramedicine. This is despite the proven impact of autonomous paramedic interpretation and subsequent lysis or catheterization lab activation in improving clinical outcomes (Nam et al., 2014). Instead, research to date has largely focused on the accuracy of paramedic interpretation (Alalwan et al., 2023; Funder et al., 2020; Wyld et al., 2023)—without first establishing what baseline list of topics this accuracy is necessary for. Similar difficulties within the medical field led the American College of Cardiology and the American Heart Association to release a joint statement in 2001 listing the expected baseline competencies for all physicians, regardless of subsequent specialty (Kadish et al., 2001). Similarly, in 2020, a Delphi determined 23 “must know” electrocardiograph diagnoses expected of undergraduate medical students (Viljoen et al., 2020). Adopting such an approach in Australian and Aotearoa New Zealand paramedicine may pave the way for improved inter-tertiary consistency and patient safety.

LIMITATIONS

This research has several limitations:

- This study used electrocardiography as an exemplar topic. This is just one of numerous topics graduates will cover and cannot be used to reflect on the depth or consistency across other topics. It may be that the inconsistency demonstrated in electrocardiography is an outlier, with other topics demonstrating higher or lower heterogeneity.
- Curriculum variation cannot be assumed to match graduate paramedic capabilities. This study measured what graduates were taught, not what they are able to do.
- The study measured lecturer-reported curriculum content rather than independently verified curriculum documentation. Additionally, curriculum content was reported by a single representative from each university, and although participants were encouraged to review course materials, some misclassification remains possible.

- The survey taxonomy was constructed by consolidating teaching materials from three institutions and may not capture ECG topics taught exclusively at other universities; the five-stage development process and expert pretesting were designed to mitigate this risk, though some content gaps cannot be excluded.
- Readers may misinterpret the most popular topics as the most important. However, this project does not determine a “correct” list of topics to include.
- The internal validity of the Theory/Practiced/Assessed categorization is, beyond the pretesting, unproven. Teaching depth is best conceptualized as a spectrum, and this categorization, therefore, provides only a superficial gauge of differences in education. To improve the validity of this categorization, participants were provided with definitions of each category at survey commencement and free-text boxes to elaborate on their responses.
- Similarly, the teaching depth measurement is categorical, not scalar; consequently, it treats the difference between “assessed” and “practiced” as the same as “assessed” and “not taught”, both receiving a binary 0 for overlap as they are different categories. These results may therefore overstate the true difference between universities.
- Participation remained voluntary and therefore some degree of self-selection bias cannot be excluded. Lecturers with stronger opinions regarding curriculum variation, standardization, or electrocardiography education may have been more likely to participate. Several factors reduce—but do not eliminate—this risk. Recruitment was undertaken from the entire target population rather than a sample, all eligible universities were approached, 94% consented to participate, and 78% ultimately returned completed surveys. Nevertheless, it remains possible that the curricula of non-participating institutions differ systematically from those represented here.
- These findings are specific to accredited undergraduate paramedicine programs in Australia and Aotearoa New Zealand, and may not be generalizable to other countries, postgraduate programs, or vocational education systems with different accreditation models.

RECOMMENDATIONS FOR PRACTICE

Three immediate uses follow from these findings. First, educators can benchmark local ECG coverage against the supplementary taxonomy to identify topics that are locally omitted or taught at unusually advanced depth; this should support curriculum review rather than ranking institutions. Second, ambulance services and other graduate employers can map induction and transition-to-practice education to topics that were inconsistently taught nationally, rather than assume uniform prior exposure; institutional aggregate data should not be used to infer an individual graduate's competence. Third, accreditation and professional bodies—including the Council of Paramedicine Deans, the Paramedicine Board, Te Kaunihera, employers, and educators—can convene a sector working group to determine whether a minimum set of ECG topics and expected educational depth is warranted.

RECOMMENDATIONS FOR RESEARCH

This research proposes two main future research recommendations. Firstly, this approach may be replicated across different subjects (such as cardiology more broadly,

and into other content such as trauma or respiratory). This could allow quantification of inconsistency at the course-wide, rather than subject-wide, level. Secondly, the results of this survey suggest it would be appropriate to develop a minimum curriculum for undergraduate electrocardiography. This may be suitably performed using a Delphi method, previously used for undergraduate medical electrocardiography (Viljoen et al., 2020)—with the panel of experts including university lecturers, but also employers from a range of industries who can inform the expected minimum standard of a registered paramedic. The 2025 UK report noted “a lack of consistency in feedback mechanisms between higher education institutions and ambulance services, which limited the ability to address any 12-lead ECG learning needs” (Health Services Safety Investigations Body, 2025, p. 5). Inclusion of a broad-based set of experts representing multiple practice environments may assist in addressing this in Australia and Aotearoa New Zealand. It is important to note that teaching “more” topics is not necessarily beneficial, as this may both overwhelm undergraduates and reduce teaching time, both of which lead to reduced comprehension (Sweller et al., 2019). Such a standardized list of topics should not be used to constrain or limit universities but instead ensure that all graduates are able to practice as autonomous paramedics safely.

CONCLUSION

This study aimed to quantify the proportion of predefined electrocardiography topics taught across programs, determine the depth at which topics are taught across programs, identify the degree of overlap and variation in content coverage between programs, and identify the opinions of lecturers on tertiary content variability. Electrocardiography education in undergraduate paramedicine programs in Australia and Aotearoa New Zealand is highly heterogeneous, with a mean SMC of 52% (range 1% to 90%). This includes topics with significant patient safety risks. In free-text, participants described it being “hard to know if we are teaching too much or not enough” and called for “a standardized minimally accepted practice level”. These findings suggest that consideration should be given to whether a minimum curriculum framework would be beneficial.

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APPENDIX A: TAXONOMY OF ELECTROCARDIOLOGY CONTENT

Subject: Anatomy

Groups	Topics
Cardiac cell types	Conductive cells - pacemakers
	Contractile cells - myocytes
	Others - fibroblasts, endothelial cells, etc
Sinoatrial node	P cells
	T cells
Intra-atrial (Bachmann's) pathway	
Internodal pathways	Anterior tract
	Middle (Wenckebach's) pathway
	Posterior (Thorel's) pathway
Atrioventricular node	Regions - atrionodal, nodal, nodal-His
	Pathways - slow and fast
	Cells - ovoid and rod cells
Bundle of His	
Bundle branches	Left anterior fascicle
	Left intermediate (septal) fascicle
	Left posterior fascicle
	Right bundle branch
Purkinje fibers	
Accessory pathways	Bundle of Kent
	Bundle of James
	Atrio-Hisian tracts
	Mahaim Fibres

Subject: Physiology

Groups	Topics
The definition of electricity	
Movement of ions across cell membranes	Voltage gated channels
	Receptor gated channels
	Sodium-Potassium pump
	Calcium ATP pump
	Sodium-Calcium exchanger
	Sodium-Hydrogen exchanger
	Magnesium regulation of channels
Gap junction depolarization	Potassium ATP channels (ischemic preconditioning)
Cardiac myocyte action potential phases	Phases - polarization, depolarization, hyperpolarization, plateau
	Voltage levels of each phase
	Membrane movement in each phase
	Refractory periods - absolute and relative
	Afterdepolarizations - early (EAD) and delayed (DAD)
Pacemaker phases and action	Phase - 0, 3, 4
	Spontaneous depolarization
	HCN channels (pacemaker or funny current generators)
	Calcium channels
Autorhythmicity	SA node
	Escape autorhythmicity - atria, AV junction, purkinje
Excitation-contraction coupling	
Myocyte phases	Phase - 0-4

Groups	Topics
Autonomic nervous system effects	Chronotropy
	Inotropy
	Dromotropy
	Lusitropy
	Bathmotropy (excitability / irritability)

Subject: Terminology

Groups	Topics
Define and discuss 'electrodes'	Positive electrodes
	Negative electrodes
'Cables' / 'wires'	
'Leads' / 'views'	
'Isoelectric line' and 'deflections'	Isoelectric line
	Deflections
	Positive deflections
	Negative deflections
	Biphasic deflections
'Waves'	P
	Q
	R
	S
	T
	U
	Delta
	J (Osborne)
	Flutter
	F waves
	Epsilon
	Pacemaker spikes
Segments	PR
	ST
	TP
Intervals	PR
	RR
	QT
	QTc
Complexes	QRS
	Atrial pacemaker
	Ventricular pacemaker
	Sequential pacemakers

Subject: Electrode placement and electrocardiograph setup

Groups	Topics
Skin preparation	
Limb lead placement	Classic / Einthoven (distal limb) placement
	Mason-Likar (torso) placement
	Lund (thigh) placement
	Equidistant rule
	Effects of limb lead placement: diagnostic quality, tethering and noise
Precordial electrode placement	V1-V6
	Cabrera electrode placement
Right lead placement	V4R/V5R placement for right ventricle only
	Complete right-sided lead placement (V1R-V6R)

Groups	Topics
Posterior lead placement	V7-V9
Other leads	Fontaine leads
	Lewis leads
Precordial lead placement in females	Over vs under breast tissue
Pre-analysis	Right patient
	Usable tracing - no artifact
	Usable tracing - at least one P-QRS-T in each lead
	Usable tracing - isoelectric baseline
	Speed - 25mm/s
	Amplitude - 10mm = 1mV
	Frequency - calibration spikes
	Frequency - 1-30Hz
	Frequency - 0.05-40Hz
	Frequency - 0.05-150Hz
	Signs of correct placement - V6 / aVL same direction
	Signs of correct placement - aVR / II opposite direction
	Signs of correct placement - R wave progression
	Signs of correct placement - aVR mostly negative
	Signs of correct placement - I and V6 mostly positive

Subject: Leads

Groups	Topics
3-leads	Einthoven's triangle
	Bipolar leads I-III
6-leads	Goldberger's terminal
	Goldberger's terminal calculation
	Augmented limb leads / Unipolar aVL, aVR, aVF
12-leads	Wilson's common terminal
	Wilson's common terminal calculation
	Precordial leads V1-V6 printout format
	Cabrera printout format
	Contiguous leads
	Reciprocal leads
Right ventricular and/or posterior leads	V4R or V5R
	V7-V9

Subject: Rhythm analysis

Groups	Topics
Rate assessment	Reading the monitor
	Six second strip x 10
	Memorized scale of large boxes - 300/150/100/75/60
	Divide 300 by large boxes
	Divide 1500 by small boxes
Regularity	Regular
	Regularly irregular
	Irregularly irregular
P wave assessment	Upright
	Uniform
	Normal morphology
	P:QRS of 1:1
PR interval assessment	0.12 - 0.2

Groups	Topics
QRS assessment	<0.12 normal
	0.1-0.12 delayed conduction
	>0.12 wide

Subject: Sinus rhythm

Groups	Topics
Normal sinus rhythm	

Subject: Dysrhythmias

Groups	Topics
Ectopic sites and escape sites	Ectopic sites - PAC, PJC, PVC
	Escape sites - atrial, junctional, ventricular
Sinus dysrhythmias	P cell pathology
	Sinus dysrhythmia
	Sinus tachycardia
	Sinus bradycardia
	Sinus arrest
	Sick sinus syndrome generally
Sinus exit blocks	Sinus exit blocks generally
	T cell pathology
	1st degree
	2nd degree Type 1
	2nd degree Type 2
	3rd degree
Atrial dysrhythmias	Ectopic atrial rhythm
	Ectopic atrial bradycardia
	Ectopic atrial tachycardia & Paroxysmal atrial tachycardia
	Multifocal atrial rhythm (Wandering pacemaker)
	Multifocal atrial bradycardia
	Multifocal atrial tachycardia
	Atrial fibrillation - generally
	Atrial fibrillation - Multiple wavelets
	Atrial fibrillation - Focal area / automaticity
	Atrial fibrillation - 'Slow' AF
	Atrial fibrillation - Rapid ventricular response
	Atrial fibrillation - Ashman phenomenon (RBBB)
	Atrial flutter - generally
	Atrial flutter - Atrial re-entry circuit
	Atrial flutter - Conduction ratio
	Atrial flutter - Type 1 (Typical) - Anticlockwise
	Atrial flutter - Type 1 (Typical) - Clockwise
	Atrial flutter - Type 2 (Atypical)
Junctional dysrhythmias	Junctional escape rhythm
	Junctional bradycardia
	Accelerated junctional rhythm
	Junctional tachycardia

Groups	Topics
Re-entrant dysrhythmias	Accessory pathways
	Lown-Ganong-Levine syndrome
	AVRT - generally
	AVRT - WPW
	AVRT - Antidromic
	AVRT - Orthodromic
	AVNRT - generally
	AVNRT - slow-fast
	AVNRT - fast-slow
	AVNRT - slow-slow
	Outflow Tract Ventricular Arrhythmias - generally
	Outflow Tract Ventricular Arrhythmias - RVOTA
	Outflow Tract Ventricular Arrhythmias - ARVD
	Outflow Tract Ventricular Arrhythmias - LVOTA
AV nodal delays / blocks	1st degree
	2nd degree Type 1 / Mobitz 1 / Wenckebach
	2nd degree Type 2 / Mobitz 2
	2nd degree 2:1 undifferentiated
	2nd degree high grade
	3rd degree / dissociation
Bundle branch blocks	LBBB
	LAFB
	LPFB
	RBBB
	Bifascicular block
	Trifascicular block
	Masquerading block
Ventricular dysrhythmias	Asystole
	Ventricular standstill
	Agonal rhythm
	Idioventricular rhythm
	Accelerated idioventricular rhythm
	Ventricular tachycardia - generally
	Ventricular tachycardia - monomorphic
	Ventricular tachycardia - RVOT tachycardia
	Ventricular tachycardia - Fascicular tachycardia
	Ventricular tachycardia - Polymorphic
	Ventricular tachycardia - Torsades de pointes
	Ventricular fibrillation - generally
	Ventricular fibrillation - coarse
	Ventricular fibrillation - fine
Paced rhythms	Atrial pacemaker
	Ventricular pacemaker
	AV sequential pacemaker
	Failure to pace
	Failure to capture

Groups	Topics
Other dysrhythmias	Supraventricular tachycardias as a group
	VT vs SVT with aberrancy
	Wide complex tachycardia
	Narrow complex tachycardia
	Compensatory pauses
	Non-compensatory pauses
	Pulseless electrical activity generally
	Littman algorithm
	Pseudo-PEA
	R on T phenomenon

Subject: 12/15/16 lead analysis

Groups	Topics
Ischemia-injury-infarction paradigms? (e.g. STEMI / STEACS / OMI)	Q-wave vs. Non-Q-wave MI paradigm
	STEMI vs. NSTEMI MI paradigm
	STEACS vs. NSTEMI MI paradigm
	OMI vs. NOMI MI paradigm
Ischemia-injury-infarction ECG signs	Hyperacute T waves
	Hyperacute T waves - limb criteria
	Hyperacute T waves - precordial criteria
	Peaked T waves
	Flattened T waves
	T wave inversion
	T wave inversion - normal in III / aVR / V1 / pediatrics
	ST segment elevation
	ST segment depression - reciprocal change
	ST segment depression - subendocardial injury
	ST segment depression - up-sloping
	ST segment depression - down-sloping
	ST segment depression - horizontal
	ST segment slope - concave
	ST segment slope - convex
	Mechanism of ST segment changes - generally
	Mechanism of ST segment changes - Effect on pumps/exchangers
	Mechanism of ST segment changes - TP segment used as baseline
	Pathological Q waves generally
Ischemia-injury-infarction ECG localization	Pathological Q waves - width criteria
	Pathological Q waves - depth criteria
	Septal infarction
	Anterior infarction
	Anteroseptal infarction
	Lateral infarction
	Anterolateral infarction
	Wraparound infarction
	Posterior infarction
	Inferior infarction
	Inferolateral infarction
	RVTMI
	LMCAO

Groups	Topics
Imposters / mimics	Left ventricular hypertrophy generally
	Left ventricular hypertrophy - Cornell criteria
	Left ventricular hypertrophy - Modified cornell
	Left ventricular hypertrophy - Sokolow-Lyon
	Left ventricular hypertrophy - Romhilt-Estes points system
	Ventricular rhythms
	Left bundle branch block
	Hyperkalemia
	Early repolarization
	Osbourne J waves
	Pericarditis
	Pericarditis - Spodick's sign
	Vasospasm (Prinzmetal's)
	Incorrect lead placement
	Paced rhythms
	Brugada - Sign Type 1
	Brugada - Sign Type 2
	Brugada - Sign Type 3
	Brugada - Syndrome
Equivalents	Reciprocal changes only visible - posterior or isolated RVMI
	LMCAO
	New left bundle
	New left bundle - Smith-modified Sgarbossa
	Wellens - Type A
	Wellens - Type B
	de Winter
	Aslanger
Chamber enlargement	Atrial chamber enlargement
	Ventricular chamber enlargement
Axis deviation	Axis deviation calculation
	Normal / Left / Right / Extreme regions
	Clinical significance
	Concordance

Subject: Miscellaneous topics

Groups	Topics
Miscellaneous	J point notching
	QT prolongation
	Long QT syndrome
	Pericardial effusion / tamponade on ECG
	Dextrocardia on ECG
	Transplantation on ECG
	Myocarditis on ECG
	Valvular patterns on ECG – generally
	Valvular patterns on ECG - Aortic stenosis
	Valvular patterns on ECG - Aortic regurgitation
	Valvular patterns on ECG - Mitral stenosis
	Valvular patterns on ECG - Mitral regurgitation
	Valvular patterns on ECG - Mitral prolapse
	Hypertrophies on ECG – generally
	Hypertrophies on ECG - Right atrial enlargement / P pulmonale
	Hypertrophies on ECG - Left atrial enlargement / P mitrale
	Hypertrophies on ECG - Dual atrial enlargement
	Hypertrophies on ECG - Right ventricular hypertrophy / strain
	Left ventricular aneurysm on ECG
	Dilated cardiomyopathy on ECG
	Hypertrophic cardiomyopathy on ECG
	Takotsubo cardiomyopathy on ECG
	Electrical alternans
Cerebral patterns	Raised intracranial pressure on an ECG
Pulmonary patterns	McGinn White sign (SIQ3T3)
	Pneumothorax on ECG
	Pulmonary hypertension on ECG
Metabolic patterns	Hypocalcemia ECG
	Hypercalcemia ECG
	Hypokalemia ECG
	Hyperkalemia ECG
	Hypomagnesemia ECG
	Hypermagnesemia ECG
Endocrine patterns	Hypothyroidism on ECG
	Hyperthyroidism & thyrotoxicosis on ECG
Toxicity patterns	Potassium efflux channel blocking drug toxicity
	Sodium channel blocker toxicity
	Sodium–potassium ATPase blocker toxicity
	Calcium channel blocker toxicity
	Beta blocker toxicity
Population variances	Indigenous
	Elderly
	Pediatrics
	Obstetrics
	Neonates

APPENDIX B: PRETEST SURVEY DESIGN FEEDBACK

Critical Care Paramedic & Paramedic Educator

- Email conversation, June 2024.
- 'Firstly, love it. This is amazing. Incredibly comprehensive. Well written. It might take a while, but it's really easy to move through. This was great. Well written. No other typos. And it all flowed well.. The second photo was just me clarifying something. Overall, there isn't anything else I would change. The survey flowed really well. I didn't find any other issues. I think it is a fantastic study and something that I have been preaching about at work. Particularly, since doing that ECG course. The variability in graduates' understanding of ECGs is unbelievable. I have grads who can barely differentiate sinus rhythm from AF, and the concept of a bundle branch block is completely foreign, let alone differentiating a STEMI mimic.'
- Sent a picture of the question on mechanism of ST segment elevation stating that it needed re-wording, with the comment 'The clarification was that the ST segment is measured from the TP interval.' This change was made.

Critical Care Paramedic

- Email conversation, June 2024.
- 'It's probably the limit that you'd want to do. I'll have a think but no real specific feedback apart from definitely not making it longer. I did it on the computer so can't speak for how it truly feels on a phone.'
- No further comments. No changes made.

Community Paramedic & Paramedic Educator

- Face to face conversation, 16/6/24.
- No specific feedback. No changes made.

University Lecturer who has taught electrocardiographs

- Telephone conversation, June 2024.
- Concern was that lecturers themselves may not know what the topics are, so suggested inserting definitions.
- No further comments. Insertion of definitions to be discussed with team.

University Lecturer who has taught electrocardiographs

- Email, June 2024.
- 'I have finally looked at the survey. I can see the effort and time this would have taken. It's a great initiative, and one very relevant to the accreditation processes Uni's are now going through. It reads well and is as brief as it can be.'
- No further comments. No changes made.

APPENDIX C: R CODE

Note – for a reader to perform the analysis themselves directly:

- Download the dataset from FigShare (https://figshare.com/articles/dataset/Data-set_xlsx/29387729)
- Merge the 11 sheets into one sheet
- Remove the headers (column A, rows 1-2) and summaries (rows 18-23)
- Run our code below

```
library(superheat)
```

```
library(readxl)
```

```
library(tidyverse)
```

```
library(hrbrthemes)
```

```
library(writexl)
```

```
library(e1071)
```

```
# Set up and preparation of data
```

```
x<-Dataset|>as.matrix()
storage.mode(x)<- "character"
x[is.na(x)|trimws(x)==""]<-NA_character_
n<-nrow(x); p<-ncol(x)
unis<-paste0("University ",1:n)
valid<-c("Not taught","Theory only","Practiced","Assessed")
engaged<-c("Theory only","Practiced","Assessed")
cat("Universities:",n,"\nTopics:",p,"\nResponses:",length(x),
    "\nNull responses:",sum(is.na(x)),
    paste0(" ",round(mean(is.na(x))*100,2),"%\n"))
unexpected<-setdiff(unique(na.omit(as.vector(x))),valid)
if(length(unexpected)) warning("Unexpected values: ",paste(unexpected,collapse=", "))
```

```
# SMC (simple matching coefficient) calculations
```

```
smc<-function(a,b){
  ok<-!is.na(a)&!is.na(b)
  if(!any(ok)) return(NA_real_)
  mean(a[ok]==b[ok])}
smc_mat<-outer(1:n,1:n,Vectorize(function(i,j) smc(x[i,],x[j,])))
dimnames(smc_mat)<-list(unis,unis)
diag(smc_mat)<-NA_real_
coef<-smc_mat[lower.tri(smc_mat)]
stats<-tibble(
  Measure=c("Mean SMC","Median SMC","Q1","Q3","Minimum","Maximum","Skewness","Ex-
  cess kurtosis"),
  Result=c(mean(coef,na.rm=TRUE),median(coef,na.rm=TRUE),
    quantile(coef,.25,na.rm=TRUE),quantile(coef,.75,na.rm=TRUE),
    min(coef,na.rm=TRUE),max(coef,na.rm=TRUE),
    skewness(coef,na.rm=TRUE,type=3),kurtosis(coef,na.rm=TRUE,type=3)))
print(stats)
```

Comparing each university against each other

```
pairs<-expand_grid(University_1=1:n,University_2=1:n)|>
  filter(University_1<University_2)|>
  rowwise()|>
  mutate(
    Jointly_valid=sum(!is.na(x[University_1,])&!is.na(x[University_2,])),
    Matching=sum(x[University_1,!is.na(x[University_1,])&!is.na(x[University_2,])]==
      x[University_2,!is.na(x[University_1,])&!is.na(x[University_2,])]),
    SMC=Matching/Jointly_valid,
    SMC_percent=SMC*100)|>
  ungroup()|>
  arrange(desc(SMC))
print(slice_min(pairs,SMC,with_ties=TRUE))
print(slice_max(pairs,SMC,with_ties=TRUE))
```

Saving the results

```
smc_pct<-ifelse(is.na(smc_mat),NA_character_,paste0(round(smc_mat*100),"%"))
dim(smc_pct)<-dim(smc_mat)
dimnames(smc_pct)<-dimnames(smc_mat)
write_xlsx(
  list(
    Matrix=cbind(University=unis,as.data.frame(smc_pct,check.names=FALSE)),
    Pairwise=pairs,
    Statistics=stats),
  "Pairwisematrix.xlsx")
```

Classifying topics

```
topic_summary<-map_dfr(1:p,function(j){
  z<-na.omit(x[,j])
  u<-unique(z)
  same<-length(z)>0&&length(u)==1
  tibble(
    Topic=j,
    Valid=length(z),
    Null=n-length(z),
    All_same=same,
    All_same_value=if(same) u else NA_character_,
    All_engaged=length(z)>0&&all(z%in%engaged),
    Mixed=("Not taught"%in%z)&&any(z%in%engaged))|>
  mutate(
    Classification=case_when(
      All_same&All_same_value=="Not taught"~
        "Consistent: not taught at any university",
      All_same&All_same_value%in%engaged~
        "Consistent: taught at all universities to the same level",
      !All_same&All_engaged~
        "Inconsistent: taught at all universities, to different levels",
      Mixed~
        "Inconsistent: taught at some universities, not at others",
      TRUE~"Unclassified"))
topic_counts<-topic_summary|>count(Classification,name="Value")
print(topic_counts)
```

```

write_xlsx(topic_summary,"Topics.xlsx")
get_n<-function(label){
  z<-topic_counts|>filter(Classification==label)|>pull(Value)
  ifelse(length(z),z,0)}
n_all_diff<-get_n("Inconsistent: taught at all universities, to different levels")
n_some<-get_n("Inconsistent: taught at some universities, not at others")
n_none<-get_n("Consistent: not taught at any university")
n_same<-get_n("Consistent: taught at all universities to the same level")

```

Figure 1

```

fig1_df<-tibble(
  Category=c(
    "Inconsistent: taught at all universities, to different levels",
    "Inconsistent: taught at some universities, not at others",
    "Consistent: not taught at any university",
    "Consistent: taught at all universities to the same level"),
  Value=c(n_all_diff,n_some,n_none,n_same)
)|>mutate(Category=paste0(Category," (n=",Value,")"),x="")
fig1<-ggplot(fig1_df,aes(x=x,y=Value,fill=Category))+
  geom_col(width=.5)+
  labs(title="Numbers of Topics by Consistency",x=NULL,y="Number of topics",fill=NULL)+
  scale_fill_manual(values=c("#002060","#51dff8","#489ff6","#eccfed"))+
  scale_y_continuous(breaks=c(0,50,100,150,200,250,300,350,p),
    limits=c(0,p),expand=c(0,0))+
  theme_minimal()+
  theme(axis.text.x=element_blank(),axis.ticks.x=element_blank())
print(fig1)
ggsave("Figure 1.jpeg",fig1,width=10,height=6,dpi=1200)

```

Figure 3

```

dimnames(smc_mat)<-list(as.character(1:n),as.character(1:n))
pal<-colorRampPalette(c("white","#51dff8","#002060"))(100)
jpeg("Figure 3.jpeg",width=11,height=9,units="in",res=1200)
superheat(
  smc_mat,
  scale=FALSE,
  heat.pal=pal,
  heat.lim=c(0,1),
  heat.na.col="#002060",
  grid.hline=FALSE,
  grid.vline=FALSE,
  title="Figure 3: Heatmap of Simple Matching Coefficients",
  title.size=6,
  title.alignment="center",
  legend.breaks=c(0,1),
  legend.num.ticks=5)
dev.off()

```

Figure 4

```

set.seed(42)
fig4<-tibble(Coefficient=coef,Name="SMC")|>
  ggplot(aes(Name,Coefficient))+

```

```
geom_violin(trim=FALSE,fill="#51dff8",alpha=.4,color=NA)+
geom_jitter(color="#002060",size=1.5,alpha=.8,width=.15)+
geom_boxplot(width=.15,outlier.shape=NA,alpha=.4,fill="#002060")+
coord_flip()+
scale_y_continuous(limits=c(0,1),breaks=c(0,.25,.5,.75,1),
                    labels=scales::percent_format(accuracy=1),
                    name="Simple Matching Coefficient")+
theme_ipsum()+
theme(
  legend.position="none",
  plot.title=element_text(size=18,face="plain",hjust=.5),
  axis.title.y=element_blank(),
  axis.text.y=element_blank(),
  axis.ticks.y=element_blank() )+
ggtitle("Figure 4: Distribution of Simple Matching Coefficients Across University Pairs")
ggsave("Figure 4.jpeg",fig4,width=10,height=6,dpi=600)
```

Figure 5

```
depths<-as.data.frame(x)|>
mutate(University=unis)|>
pivot_longer(-University,names_to="Topic",values_to="Value")|>
filter(Value%in%valid)|>
count(University,Value,name="Count")|>
complete(University=unis,Value=valid,fill=list(Count=0))|>
mutate(
  University=factor(University,levels=unis),
  Value=factor(Value,levels=c("Assessed","Practiced","Theory only","Not taught")))
fig5<-ggplot(depths,aes(University,Count,fill=Value))+
geom_col()+
labs(title="Figure 5: Teaching Depth by University",x="University",
      y="Number of topics",fill="Category")+
scale_fill_manual(values=c(
  "Assessed"="#002060",
  "Practiced"="#489ff6",
  "Theory only"="#51dff8",
  "Not taught"="#ecccfd"))+
scale_y_continuous(limits=c(0,p),breaks=c(0,100,200,300,p),expand=c(0,0))+
theme_minimal()+
theme(axis.text.x=element_text(angle=45,hjust=1))
ggsave("Figure 5.jpeg",fig5,width=10,height=6,dpi=600)
```

Summing uni totals

```
university_totals<-depths|>
pivot_wider(names_from=Value,values_from=Count,values_fill=0)|>
mutate(
  Non_null=Assessed+Practiced+`Theory only`+`Not taught`,
  Null=p-Non_null)
write_xlsx(university_totals,"University_category_totals.xlsx")
```

Sensitivity analysis excluding university 7

```
x7<-x[,-7,,drop=FALSE]
m7<-outer(1:nrow(x7),1:nrow(x7),Vectorize(function(i,j) smc(x7[i,],x7[j,])))
```

```
diag(m7)<-NA_real_
c7<-m7[lower.tri(m7)]
sensitivity<-tibble(
  Measure=c("Mean SMC","Median SMC","Q1","Q3","Minimum","Maximum","Skewness","Ex-
cess kurtosis"),
  Result=c(mean(c7,na.rm=TRUE),median(c7,na.rm=TRUE),
    quantile(c7,.25,na.rm=TRUE),quantile(c7,.75,na.rm=TRUE),
    min(c7,na.rm=TRUE),max(c7,na.rm=TRUE),
    skewness(c7,na.rm=TRUE,type=3),kurtosis(c7,na.rm=TRUE,type=3)))
print(sensitivity)
write_xlsx(sensitivity,"University_7_sensitivity_analysis.xlsx")
conflict<-apply(x7,2,function(z){
  z<-na.omit(z)
  "Assessed"%in%z&&"Not taught"%in%z})
conflict_topics<-tibble(Topic=1:p,Maximum_conflict=conflict)|>
  filter(Maximum_conflict)
cat("Maximum-conflict topics excluding University 7:",
  nrow(conflict_topics),"of",p,
  paste0(" (",round(nrow(conflict_topics)/p*100,1),"%)\n"))
write_xlsx(conflict_topics,"Maximum_conflict_topics_excluding_University_7.xlsx")
```

Summary

```
summary_output<-tibble(
  Measure=c(
    "Universities","Topics","Total responses","Null responses","Null responses (%)",
    "Consistently not taught","Consistently taught at same depth",
    "Taught at all universities to different depths",
    "Taught at some universities and not others",
    "Pairwise comparisons","Mean SMC (%)","Median SMC (%)","Q1 (%)","Q3 (%)",
    "Minimum SMC (%)","Maximum SMC (%)","Skewness","Excess kurtosis",
    "Maximum-conflict topics excluding University 7",
    "Maximum-conflict topics excluding University 7 (%)",
    "Sensitivity mean SMC (%)","Sensitivity median SMC (%)",
    "Sensitivity minimum SMC (%)","Sensitivity maximum SMC (%)"),
  Result=c(
    n,p,length(x),sum(is.na(x)),mean(is.na(x))*100,
    n_none,n_same,n_all_diff,n_some,length(coef),
    mean(coef,na.rm=TRUE)*100,median(coef,na.rm=TRUE)*100,
    quantile(coef,.25,na.rm=TRUE)*100,quantile(coef,.75,na.rm=TRUE)*100,
    min(coef,na.rm=TRUE)*100,max(coef,na.rm=TRUE)*100,
    skewness(coef,na.rm=TRUE,type=3),kurtosis(coef,na.rm=TRUE,type=3),
    nrow(conflict_topics),nrow(conflict_topics)/p*100,
    mean(c7,na.rm=TRUE)*100,median(c7,na.rm=TRUE)*100,
    min(c7,na.rm=TRUE)*100,max(c7,na.rm=TRUE)*100))
write_xlsx(summary_output,"Analysis_summary.xlsx")
cat("Analysis complete.\n")
```