Disciplinary Differences in Blended Learning Design: A Network Analytic Study

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ABSTRACT

Learning design research has predominately relied upon survey- and interview-based methodologies, both of which are subject to limitations of social desirability and recall. An alternative approach is offered in this manuscript, whereby physical and online learning activity data is analysed using Epistemic Network Analysis. Using a sample of 6,040 course offerings from 10 faculties across a four year period (2016-2019), the utility of networks to understand learning design is illustrated. Specifically, through the adoption of a network analytic approach, the following was found: universities are clearly committed to blended learning, but there are considerable differences both between and within disciplines.

KEYWORDS

faculty, learning activity types, epistemic network analysis

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1 INTRODUCTION

The instructional movements of blended learning, flipped classroom, small-group learning, e-learning, and active learning have resulted in an ever-growing number of publications. For example, recent meta-analyses have identified 51 quality studies on blended learning [28] and 144 quality studies of flipped classrooms [27]. From this research, it appears universities are shifting where students learn and how by utilising more technology, peer learning, and educator interactions. However, after the progress of these education movements, it is unknown how the composition of teaching and learning activities has transpired in real-world university classrooms. More specifically, are these movements changing teaching practices for all students or students of certain disciplines?

Researchers have often classified academic disciplines according to whether they are pure STEM (e.g., physics, chemistry), applied STEM (e.g., engineering, medicine, technology), pure non-STEM (e.g., social sciences), and applied non-STEM (e.g., education, architecture) [21, 28]. Traditionally, academics from these different types of discipline classifications report divergences in their teaching practices. Applied discipline educators typically report a focus on developing students' practical skills and pragmatic problem-solving ability, whereas pure discipline educators emphasise the testing of ideas through argumentation [21]. Compared with STEM disciplines, non-STEM disciplines' educators are more likely to report the use of active learning, tutorials, and collaborative learning [2, 4]. Non-STEM educators typically see their role as facilitators to encourage deep learning and student development [15]. In contrast, STEM educators describe a greater use of assessments, tutorials, and computer-based activities to teach their students subject matter knowledge and concepts [2, 3].

The majority of the literature examining differences between disciplines' teaching practices has used surveys and interviews. Also, researchers have analysed written syllabi, course materials, and educator reflections [15]. Although these methodologies are ideal for capturing educators' beliefs and perceptions, phenomenon including response bias, social desirability bias, and recall bias may limit them as tools to evaluate what is occurring in actual learning environments. Also, the unit-of-analysis is limited to individual teachers and classes. To address these limitations, we posit that and demonstrate how *data readily available in the institutional learning management and timetabling systems can provide insights regarding differences in teaching practices across disciplines.*

Specifically, we propose a network analytic method that can be used to study learning designs in blended environments by analysing data about activities in physical and online spaces. By conducting a network analysis of teaching practices (reflected through learning designs) of different academic units of a university, we can compare and contrast practices across STEM, non-STEM, pure, and applied disciplines. Due to the nature of non-STEM and STEM disciplines, Vo and colleagues suggest that STEM disciplines are better suited for blended learning [28]. In fact, their meta-analysis revealed a larger effect size for blended learning interventions in STEM disciplines than non-STEM disciplines. They argued that the online components of blended learning have a stronger benefit for applied disciplines, because students gain applied practice with virtual environments, virtual patients, and simulations. By contrast non-STEM disciplines, by nature, is more likely to require high quality face-to-face discourse to develop students' understanding of complex topics [1]. Although meta-analyses identified an array of subjects utilising blended learning and flipped classroom models, blended learning research most commonly occurs in medicine and health care [20] and flipped classroom research is most commonly conducted in mathematics and science [5]. These results may allude to a shift in how STEM and applied disciplines approach student learning. Authors from applied STEM disciplines have noted their concern for the changing world of work as the reason for curriculum reforms [14]. They often describe workers' ability to easily access information on the Internet that was previously housed only in textbooks and professors' memory. As a consequence, applied STEM disciplines have shifted their focus from ensuring learners know everything to ensuring learners can problem solve, create new information, and think critically. Therefore, the STEM disciplines' teaching practices may now appear more and more similar to their non-STEM counterparts who have always been less focused on knowledge acquisition.

Research in learning analytics has acknowledged the importance of learning design [11, 16]. Existing research demonstrates that analytics can be used to detect the distance between pedagogical intentions of the designers and the enactment of these intentions in the designs themselves [22], to facilitate the community of teachers to engage into the co-design process [13], and to unveil interactions between types of learning activities in online education[23]. Existing studies have also made use of large institutional datasets to understand how learning design was associated with student success [26]. However, there is limited research in learning analytics that looked at disciplinary similarities, differences and changes in learning designs using readily available data and large sample sizes.

The purpose of this study was to understand how blended learning designs across academic disciplines are constituted in terms of physical and online activities. The study was conducted using data from one Australian higher education institute over four years. Specifically, the study addressed the following research questions:

- What are the differences in blended learning designs in terms of physical and online learning activity offerings across academic disciplines? (Research Question 1)
- What information can network subtraction plots provide with regards to understanding faculties both closely and distantly positioned in dimensional space? (Research Question 2)
- How do academic disciplines change their blended learning designs over several academic years? (Research Question 3)

2 METHOD

Sample

All 10 academic units (i.e., faculties) at the study site were included: Art, Design and Architecture, Arts, Business, Education, Engineering, Information Technology, Law, Medicine, Pharmacy, and Science (Table 1). For clarification purposes, the faculty of Art, Design and Architecture is independent of the faculty of Arts, which is made up of humanities, social

Table 1: Discipline classification of 10 faculties according to [21, 28]

Discipline classification	Faculties
Applied STEM	Pharmacy Medicine Engineering Information technology
Pure STEM	Science
Applied non-STEM	Law Business Education Art, Design and Architecture
Pure non-STEM	Arts

Table 2: Number of Course Offerings per Faculty

Faculty	*n*	%
Art, Design and Architecture	536	8.87
Arts	1694	28.00
Business	905	15.00
Education	425	7.04
Engineering	447	7.40
Information Technology	327	5.41
Law	52	.86
Medicine	894	14.80
Pharmacy	220	3.64
Science	540	8.94

sciences, and music. The obtained data was restricted to a four year period (2016-2019), the two main semesters (Semester 1 and Semester 2), and undergraduate level courses (course levels 1 to 3).

Course offerings sampled from these 10 faculties totalled 6,040 (2,077 unique course offerings); the course counts and percentage values per faculty are presented in Table 2. A detailed breakdown of the course offering counts by year (2016-2019) and course level (1-3) are provided in Table 3.

Data

Exploring activity types offered to students in both physical and online spaces was a main focus of this work. Data was sourced from the university course timetabling system and the learning management system (LMS). Timetabling data was structured so that each row contained such details as the course name and ID, the activity type that was booked, how many students the booking was for, the location on campus, and time of activity. LMS data was collected from the activity type tables associated with courses, using the terminology of the Moodle learning management system.

To manage the degree of diversity in the types of activity offered in these environments, two typologies were applied: a standardisation of activity type in physical learning spaces proposed by the university, and Dawson and colleagues' categorisation of LMS activity [7, 17]. Beginning with the former, the typology of activity type subsumes activities under 9 categories (see Table 4 for activity definitions) with a view of providing a standard practice to timetable bookings. The typology creation was actioned by a university committee due to 262 unique activity types existing that have been used by faculties to describe learning activities, significantly exceeding the terminology used by comparable institutions. Having a large number of idiosyncratic activity descriptions created additional difficulties to students and university staff as opaque terms conveyed little meaning. Steps were taken by two of the authors to consolidate the activity terminology and provide supplementary descriptions to convey pedagogic intent. Based on an examination of the 262 activity terms, the aforementioned 9 category typology was agreed upon (Table 4), which was applied to the 2016-2019 timetabling data to consolidate the plethora of activity terms.

The proposed categorisation of LMS activities in Dawson et al. [7, 17] is as follows: *Administration*, *Assessment*, *Content*, and *Engagement*. Proposal of these four categories was motivated by a need to manage the broad array of activities contained within LMS sites and reflect what can be considered the core purposes of these activities. Reasoning behind the application of this coding framework was based on its simplicity and interpretability – a diverse array of LMS tool labels can be collapsed into four categories. Nevertheless, adoption of this framework does make an important supposition that should be acknowledged: exclusivity, the LMS activity may serve multiple purposes and a single category ignores such fuzziness. For example, the lesson activity in Moodle usually contains quiz elements, not just content. The activities extracted from the university LMS totalled 19 in number and are listed in Table 5 with their respective categorisation, e.g., resources were categorised under *Content*. The extraction process was as follows: tables for each of the 19 LMS activities were pulled from the University database; the adopted categorisation (Table 5) was then applied.

The complete data that was subject to analysis joined together the physical and online activity coding frameworks. An example of the learning space activity offering data table is presented in Table 6. For hypothetical Course 1, students were offered *Laboratory* and *Lecture* activities, but not *Applied* or *Content* activities.

Epistemic Network Analysis

To address both research questions, the binary activity offering data was analysed using the Epistemic Network Analysis (ENA; [24]) R package [18]. ENA itself is used to model the

Table 3: Number of Courses per Faculty by Year and Course Level

Faculty	Year	2016			2017			2018			2019		
	Course Level	1	2	3	1	2	3	1	2	3	1	2	3
Art, Design and Architecture		38	57	34	39	71	36	39	66	27	40	61	28
Arts		93	172	170	93	176	169	91	167	159	89	163	152
Business		37	87	106	30	89	118	28	79	118	28	74	111
Education		32	41	50	32	34	42	28	33	38	27	33	35
Engineering		11	44	60	11	41	58	10	42	61	11	39	59
Information Technology		22	29	32	17	33	28	18	27	40	17	27	37
Law		4	7	5	4	6	4	4	4	3	4	4	3
Medicine		54	67	97	53	69	98	51	81	94	55	79	96
Pharmacy		16	20	30	13	20	30	13	19	30	10	8	11
Science		25	42	63	25	41	67	26	41	71	26	41	71

Table 4: Activity Typology and Definitions for Physical Learning Spaces

Activity	Definition
Applied	Apply discipline specific skills, supported by a subject expert
Assessment	Timed, paper-based or online activities
Laboratory	Application of theoretical knowledge to a research setting
Lecture	Learn in a large group led by an expert instructor
Practical	Activities undertaken within a simulated environment
Seminar	Group based activity led by a panel of experts
Studio	Activities that require creative solutions
Tutorial	Encourages peer engagement to answer questions based on subject material
Workshop	Small groups activities to discus and critique work from other groups

Table 5: LMS Activity Categorisation

Category	LMS Activities
Administration	Feedback, Survey
Assessment	Assign, Choice, Quiz, TurnitinTool TurnitinToolTwo, Workshop
Content	Book, Data, Equella, Glossary Lesson, Page, Resource, Scorm, Wiki
Engagement	Chat, Forum

Table 6: Hypothetical Activity Offering Data Table

	Applied	Laboratory	Lecture	Content
Course 1	0	1	1	0

strength of connections between an array of objects, using an adjacency matrix of code co-occurrence as input. Empirical work that has applied ENA initially focused upon dialogic interactions [24]; recent applications of ENA have since explored its suitability in various data sets, e.g., the evaluation of students' learning products [9], connections between values, knowledge and skills in game play [25], thematic connections between topics in research publications [6], dimensions of collaborative learning [12], and learning strategies [19]. In the current study, we used ENA to compute the co-occurrence of codes defined in Table 4 and Table 5 (13 codes in total). Once the codes were applied to the data, counts of the standardised activities were taken for each course (defined as an analysis *stanza* in this study) across year (2016-2019) and course level (1-3). As the analysis of the data was based on the co-occurrence of activities (both physical and online), counts were subsequently transformed into binary data to indicate whether the activity was offered (1) or not (0). LMS data was collected from the activity type tables associated with courses, using the terminology of the Moodle learning management system.

The binary summation data table (e.g., Table 6) was then used to create an adjacency matrix that formed the basis of the ENA. This matrix was created for each row of data, again representing the co-occurrence of codes. Adjacency matrices were then summated across a group level of interest, which for the present purpose was for *Faculty* and *Year* (Research Question 1 and 2). These cumulative adjacency matrices were then converted into adjacency vectors that represented the summated co-occurrence of codes at a particular group level. Spherical normalisation was then applied to the adjacency vector whereby each vector was divided by its length, giving the relative frequencies of code co-occurrence. Singular value decomposition was finally applied to both reduce the dimensionality and increase the variance captured.

Centroids (arithmetic mean of edge weights) for the group level of interest were then plotted in two-dimensional space, the interpretation of which is aided by a projection of those codes used for analysis (Table 4 and 5). For Research Question 1, the centroids that were plotted would be each of the 10 Faculties across the four year period. An overall network plot is also presented, which presents the average activity network across faculties. LMS data was collected from the activity type tables associated with courses, using the terminology of the Moodle learning management system. Finally, based on a selection of faculties that were meaningfully different from one another, four centroids representing each year of analysis (2016-2019) for a particular faculty were positioned in a dimensional space to explore longitudinal learning activity changes (Research Question 3). Subtraction plots are again provided to visually inspect how, if at all, a faculty changed over four years in terms of learning activities offerings.

3 RESULTS

Research Question 1: Faculty Comparisons

Centroids for the 10 faculties in two-dimensional space are presented in Figure 1a along with their respective confidence intervals. The amount of variance accounted by these two dimensions are as follows: 32.55% (x-axis; Dimension 1) and 21.85% (y-axis; Dimension 2). From visualisation alone, there is a clear separation of faculties on the x-axis (Dimension 1). Those faculties that are predominantly offering pure non-STEM or applied non-STEM subjects lie left on the x-axis, whilst those faculties typically regarded as offering pure STEM or applied STEM subjects lie right on the x-axis. Differentiation on the y-axis (Dimension 2) only appears relevant to Art, Design and Architecture; all other faculties are tightly gathered on this Dimension.

Visualising faculty placement along Dimensions 1 and 2, in isolation of what has determined such positioning, is a limited approach. To flesh these faculty differences out further, the physical and LMS activity codes can be positioned along Dimension 1 and 2 (Figure 1b as shown in the overall network for the 10 faculties; **P**, physical; **O**, online). What can be immediately taken away from Figure 1b is that there were strong co-occurrences between the LMS activities. As for physical activities, Lectures and Tutorials tended to co-occur most frequently, followed by Lectures and Laboratory activities. As regards to co-occurrences between physical and online activities co-occurring, the presence of Assessment, Content, and Engagement activities tended to co-occur with the provision of either Lecture, Laboratory, or Tutorial activities. Among these, the co-occurrence of Lectures with LMS activities (Assessment, Content, and Engagement) was the most prominent.

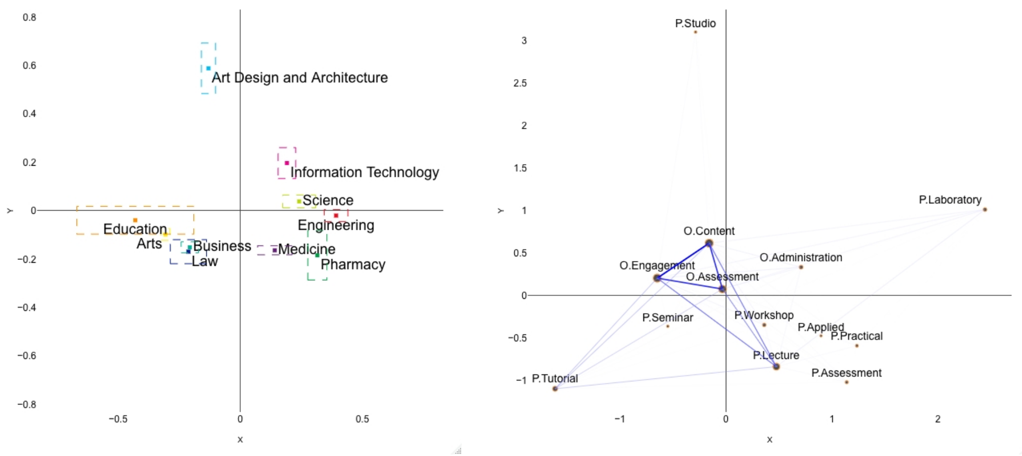
Based on the activity node placement alone, the placement of Art, Design and Architecture along Dimension 2 as courses predominately reflects the dominance of Studio activities for these courses. Take, for instance, a course on *Drawing* – the type of activities offered are more likely to be Studio-based as there will be an emphasis on creative solutions, which other activity types would not normally provide. Offering Studio activities to students of the remaining nine faculties was not common, explaining the aforementioned y-axis (Dimension 2) differentiation.

Faculties that can loosely be described as offering pure and applied STEM subjects lie to the right on Dimension 1 (x-axis; Figure 1a). It is only with the aid of Figure 1b that faculty placement is seen to be determined by an emphasis on Applied, Assessment, Laboratory, Lecture, Practical, and Workshop activities in physical spaces. This is understandable, as Applied activities focus on the application of discipline-specific skills to a scenario. The Faculty of Pharmacy provides a good illustration of offering Applied activities as there is an expectation to develop communication skills in order to transmit information back to the wider community. Similar comments can also be made of Practical activities, where student behave in a simulated environment that mirrors a realistic scenario (e.g., nursing students need to practise implementing interventions).

Assessment (Physical) activities appear to characterise the dimensional space that is assumed by applied STEM subjects. There is a possibility that these particular faculties offered assessment activities at a greater frequency than pure STEM, pure non-STEM, or even applied non-STEM faculties. Given that the faculties lying within this dimensional space can be thought of as professional degrees, this may be explained by a greater onus on evaluating skills that would be used in practice.

Laboratory based activities would characterise the majority of the faculties that lie right on the x-axis (Dimension 1). These activities are motivated by a view of applying acquired knowledge to a research setting. Despite most faculties within a small interval on Dimension 2 (y-axis), Information Technology and Science are placed higher than those faculties similarly positioned on Dimension 1 (x-axis). The latter would be suggestive of a greater emphasis on Laboratory activities for these faculties; Information Technology courses are likely to require students to learn programming languages in computer labs, whilst Science courses expect students to run lab-based experiments.

Lecture activities are often used to teach large groups of students, particularly core content material. Across each of the five faculties of focus (Engineering, Information Technology, Medicine, Pharmacy, and Science) the use of Lecture-based activities would be a common approach to cover course material. This would also be true of both the faculties of



(a) Faculty Comparison (b) Overall Network

Figure 1: Faculty Comparison and Overall Network Plots

Business and Law, which are positioned left of Dimension 2 (y-axis).

Shifting the focus to those faculties lying on the left of the x-axis (Dimension 1), there appears to be greater emphasis on Seminar- and Tutorial-based activities. A reason for adopting such activity approaches is class-size–courses in Arts total 1,649 across the four years of data so it is unlikely that classes were large, downplaying the need for Lecture-based activities. Rather, these courses would require activities align with a smaller group of students (i.e., Seminars and Tutorials).

The results of the analysis of LMS activity offering show that its utility in differentiating faculties is limited. The codes of Assessment, Content, and Engagement were closely tied together; given that these codes categorise what are core components of an LMS, the strong ties were not unexpected. Administration, in the current work, only captured two LMS activities (Feedback and Survey). The extent to which these are offered may be at a nominal level given the range of tools outside of the LMS that are capable of such functionalities.

Research Question 2: Subtraction Plots and Faculty Positions

The prior approach has been to describe faculty positions on two Dimensions using the activity node placements. A more granular approach follows, whereby faculties are compared based on their distance from one another within the two-dimensional space. Presentation of comparison results will be for those faculties closely clustered within two-dimensional space and those faculties distantly positioned from one another; determination of what faculties were similar and different was guided by Figure 1a. Due to their close positioning in the dimensional space, the faculties of Information Technology and Science were selected for the purpose of exploring faculty similarities. An argument could be made for the comparison of Business and Law due to the extent of their overlap. Law is, however, the smallest faculty in terms of course offerings and the variability in activities will consequently be small due to the amount of data available. As seen in Figure 1a, Information Technology and Science are positioned closely together in the top right quadrant; these faculties represent a greater number of course offerings so there is more variability in activity offerings. Faculties selected for the purposes of highlighting differences were as follows: Arts, Art, Design and Architecture, and Pharmacy. Again, this was informed by Figure 1a as these three faculties are distantly positioned in two-dimensional space; network node placement was also suggestive of these three faculties being characterised by different activity offerings (Figure 1b).

Closely Positioned Faculties. To compare faculties that can be argued as having similar positions within two-dimensional space, a subtraction plot is used (Figure 2; differences between two compared networks are visualised using the edge weights of the residuals). At a glance, it can be seen that even though centroids for Information Technology and Science were closely positioned in two-dimensional space (Figure 1a), the activity offerings for each faculty do show visual differences. Information Technology has a greater co-occurrence of Studio- and Lecture-based activities. Science, on the other

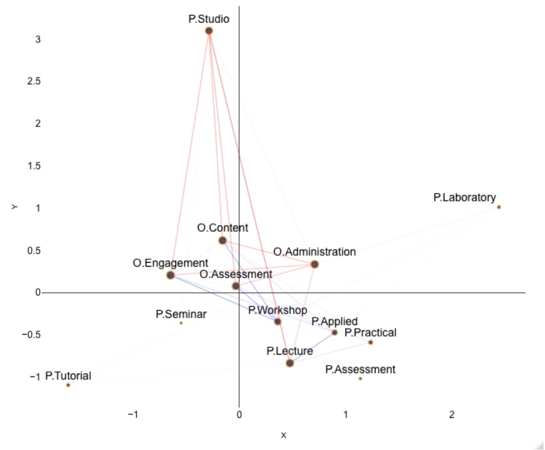


Figure 2: Subtraction Plot for the Information Technology (Red) and Science (Blue) Activity Offering Networks

hand, has more co-occurrences between Workshop activities and the online activities of Assessment and Engagement; Applied and Lecture activities also appeared to co-occur more frequently for Science. Together, it appears that while such faculties may appear to be close from centroid positioning, there remains a distinctiveness in what activities are offered to students.

Distantly Positioned Faculties. Based on both the x- and y-axis separations, Arts, Art, Design and Architecture, and Pharmacy were compared (Figure 1a; subtraction plots were also used (Figure 3).

Consider Figure 3a as a starting point, which compares the faculties of Arts and Pharmacy. A clear difference in the activity offerings can be seen that shows Arts to emphasise the offering of Tutorial activities, which also appear to co-occur with Lecture and Seminar activities within physical spaces; greater co-occurrences were also found with the online activities of Assessment, Content, and Engagement. Compared to Arts, Pharmacy offered a greater variety of activities to students in the form of Applied, Assessment, Laboratory, Lecture, Practical, and Workshop activities. In particular, Assessment and Lecture activities have the highest co-occurrence.

A clear differentiation between Art, Design and Architecture and Pharmacy activity offerings is presented in Figure 3b. For Art, Design and Architecture, the activity type that dominates this faculty is the provision of Studio activities; strong co-occurrences between Studio and LMS Content activities and between Studio and LMS Engagement activities can also be noted. Pharmacy is again shown to be more diverse in its activity offering for students as it offers Applied, Laboratory, and Practical activities, for example. Similar observations can also be taken from Figure 3c that reiterates the importance of Studio-based activities to Art, Design and Architecture; Arts does not have the activity variety of Pharmacy, but the plot does indicate a preponderance of Lecture, Seminar, and Tutorial activities in addition to LMS activities.

Research Question 3: Faculty Changes by Year

Selection of faculties for Research Question 3 was guided by the findings of Research Question 2 – faculties well separated in two-dimensional space were selected. Thus, Art, Design and Architecture, Arts, and Pharmacy were chosen as the exemplar faculties to explore activity offering changes over four years (2016-2019).

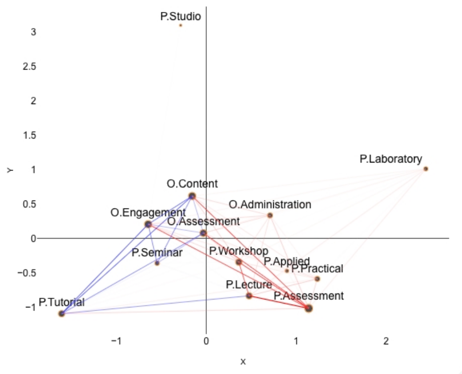
Figure 4a plots four centroids per faculty in two-dimensional space (faculty names have been abbreviated for readability: ADA, Art, Design and Architecture; A, Arts; and P, Pharmacy). Visual inspection of the centroid placement showed that the faculty of Arts does not display any substantial movement over four years. Art, Design and Architecture appeared to show a more discernible pattern of movement over this time period, specifically moving up along the y-axis (Dimension 2), towards Studio-based activities. Pharmacy appears also to have moved over the four year period, progressing right along the x-axis (Dimension 1) and up along the y-axis (Dimension 2), towards Laboratory activities.

Additional granularity about faculty learning activity offerings over time can be obtained from subtraction plots. For illustrative purposes, the Pharmacy faculty was selected, specifically the years of 2016 and 2019 (Figure 4b). Reasoning behind the selection of Pharmacy and the years of 2016 and 2019 were two-fold: Arts has, based on Figure 4a, not shown a substantial change in its dimensional positioning over four years; Art, Design and Architecture has been more pronounced in its four year trajectory, but remains fixated within a quadrant characterised by Studio activities. Pharmacy, from 2016 to 2019, has shown a large transition that brings it closer to the upper right quadrant (Figure 4a); an inference made from such movement would be a notable change in learning activity offerings.

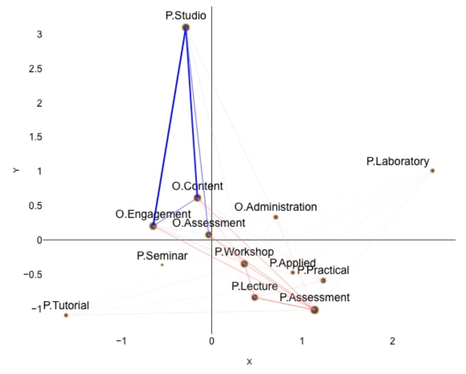
Figure 4b presents a subtraction plot for the co-occurrence of activities in Pharmacy during 2016 and 2019. In 2016, there was greater focus on offering Lecture, Practical, and Tutorial activities to students. The shift that appears to have taken place from 2016 to 2019 (Figure 4a) appears to be a decline in the co-occurrence of activities such as Tutorials and Practicals. In their place, Pharmacy appears to be gradually increasing the offering of Applied, Laboratory, and Workshop activities; increases in LMS activities are also shown.

4 DISCUSSION

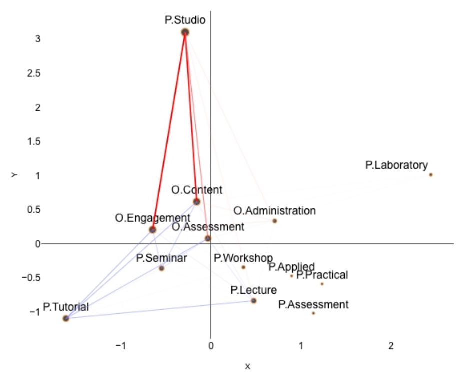
Evaluating the application of a network analysis approach to understand inter-disciplinary learning designs was the motive of this work. Efficacy of the network analysis approach is



(a) Pharmacy (Red) and Arts (Blue)



(b) Pharmacy (Red) and Art, Design and Architecture (Blue)

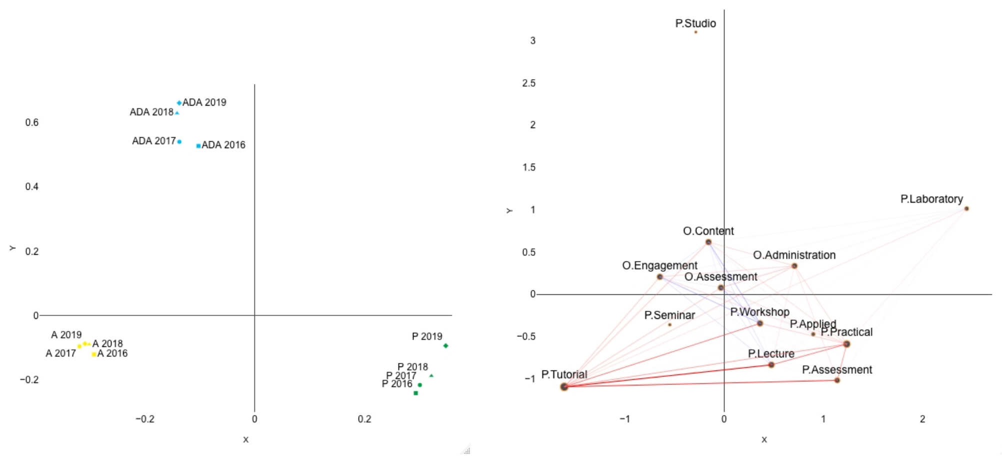


(c) Arts (Blue) and Art, Design and Architecture (Red)

Figure 3: Subtraction Plots for Faculty Difference Comparisons

attested by the results provided. For one, the combined information of faculty centroid and activity (physical and online) positioning plots were used to explore cross-disciplinary differences in learning designs (physical and online; Research Question 1; Figure 1). A surmised account of these results is as follows: pure and applied STEM disciplines offer an array of learning activities that are clearly discernible from pure and applied non-STEM disciplines. Such differences are further clarified through the application of subtraction plots (Figure 2 and Figure 3), the output of which enables researchers to understand what learning activities co-occur more frequently (Research Question 2). Finally, network analysis can be used to model faculty activity offerings over a period of time (Research Question 3; Figure 4).

The study shows that learning activities are frequently facilitated in the LMS space, combined with lectures as the dominant activities in the physical spaces (Figure 1b shows co-occurrence among these four activities are the most prominent). Three types of physical activities appear to be discipline-specific: Studio- and Tutorial-based learning are more prominent among non-STEM disciplines whereas Laboratory-based learning prevails among STEM disciplines. However, counter to the arguments made by Vo et al. [28] and Arbaugh et al. [1] that STEM disciplines benefit more from online components than non-STEM disciplines, our analysis shows that Arts as a non-STEM faculty demonstrates more use of online activities compared to Pharmacy (as shown in the subtraction plot Figure 3a). This suggests that learning in the Arts discipline are becoming more blended, which indicates a potential need for the support of online and blended course design, such as skill training and dedicated learning technologists.



(a) Four Year Changes in Art, Design and Architecture, Arts, and Pharmacy

(b) Pharmacy 2016 (Red), 2019 (Blue) Subtraction Plot

Figure 4: Exploring Faculty Activity Offerings over Four Years

The network analysis also allows us to observe the changing patterns in the usage of online and campus resources over the years. This provides important information for researchers, educators, managers and policy makers to examine the evolving trends of pedagogical approaches in different disciplines, the needs for curriculum redesign, the capacity of learning resources, and the maturity of skills in utilising existing resources among both teachers and students.

The study extends the existing literature that looks at links between learning analytics and learning design. Specifically, the analytic approach proposed in this paper offers a measure of differences in learning designs (e.g., centroids in two-dimensional space and distances between disciplines) in terms of the utilisation of resources online and in physical spaces. This contributes important insights into the design and implementation of learning analytics, highlighting the similarities and differences between disciplines in terms of how learning is designed, how it should be interpreted in the context, and what kinds of data are meaningful to collect and analyse. Moreover, this also enables for creating predictive models that account for differences in instructional designs and disciplines as noted to be important in the learning analytics literature [8, 11].

This work also brings methodological novelty to the study of learning design. Consider the work of Nguyen et al. [23], which applied social network analysis to study weekly activity co-occurrences, as a comparative approach. In the latter, plots were restricted to visualising the co-occurrences within a specific faculty [23]; data was also restricted to digital spaces. The approach adopted here extends such work in four ways: first, by presenting an analysis of learning design using data from physical and digital spaces; second, by quantifying co-occurrences of faculty learning activities within the same dimensional space (Research Question 1); third, by enabling visual and qualitative inferences that are supported by quantitative data (Research Question 2); and fourth, by quantifying changes in course designs within and across disciplines (Research Question 3). Comparatively speaking, the ENA approach can then be seen to offer a degree of insight that is not attainable from the approach adopted by Nguyen et al. [23].

5 LIMITATIONS AND FUTURE WORK

The unit of analysis (faculty) in this study is defined in the context of an Australian university. Thus, the results are not intended to be generalised. However, the network analysis used in this study demonstrates potential to explore learning design and resource demand in any given educational institution. One limitation in this study is that a faculty tends to include multiple types of disciplines and programs, which are not always uniformly 'applied' or 'pure' [21, 28]. For example, the Biomedical Sciences Programme (pure) is placed in the Faculty of Medicine, which is considered as an applied STEM discipline. Future studies may use epistemic network analysis to explore resource usage within a faculty to capture the differences between programmes.

The focus of this work has been on a binary representation of learning activity offerings. Although this data transformation aligned with the questions of the research – exploring whether faculties can be characterised by what learning activities are offered – details of activity frequency are lost. The next steps should then be to explore how details of learning activity frequency can build upon the presented findings through the use of a weighted matrix approach. A possible insight from the conjunction of activity frequency and time would be a granular understanding of activity offering. For example, the findings of Research Question 3 were indicative of faculty changes over four years, but only with regards to what was offered. Variations in activity frequencies over time were not captured; only a weighted matrix approach would offer such details. Nevertheless, the results align with the critical comments of French and Kennedy [10]: students are being offered an integration of teaching methods (Laboratory, Practical, and Tutorial activities) at university, not just Lectures.

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