Research article

Relative importance of professional practice and engineering management competencies

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Abstract

Problem- The professional practice of engineering always involves engineering management, but it is difficult to know what specifically to include in the undergraduate curriculum. ***Approach-*** The population of New Zealand practising engineers was surveyed to determine the importance they placed on specific professional practice and engineering management competencies. ***Findings-*** Results show that Communication and Project planning were the two most important topics, followed by others as identified. The context in which practitioners use communication skills was found to be primarily with project management, with secondary contexts identified. The necessity for engineers to develop the ability to use multiple soft skills in an integrative manner is strongly supported by the data. ***Originality-*** This paper is one of only a few large-scale surveys of practising engineers to have explored the soft-skill attributes. It makes a didactic contribution of providing a ranked list of topics which can be used for designing the curriculum and prioritising teaching effort, which has not previously been achieved. It yields the new insight that combinations of topics are sometimes more important than individual topics.

Keywords*: engineering management; professional practice; graduate attributes; Washington Accord; project management; curriculum; syllabus; communication*

1 Introduction

One of the defining characteristics of an engineering degree is that it teaches the student to apply mathematics and a range of engineering sciences to the solution of technology problems. However these problems are embedded in a soft context: they are solved by teams of people working economically in organisations, and the reason to solve them is to add value to a client, customer, or society. Hence there is a need for graduates to have skills in the management of people and organisations and to create technological solutions that are aligned to society's needs. Furthermore a natural career path for practising engineers is to progress into management of engineering ventures [1]. Thus the engineering profession absolutely expects the inclusion of professional-practice and engineering-management skills within a professional engineering degree. An international collaboration exists between the individual national professional bodies, in the form of the International Engineering Alliance (IEA). Thus the profession has developed an internationally consistent set of expectations of the professional content of an engineering education. These are expressed in the

Washington-, Sydney-, and Dublin-Accord for professional engineering, engineering technology, and technician engineering respectively [2]. The graduate attributes of the Washington Accord (WA) are shown in Table 1. The profession then actively checks, through the accreditation process, that this does occur.

That undergraduates need to develop knowledge and skills in professional practice and engineering management is therefore not in question. The difficulty is that the Accords are worded in general rather than specific terms, e.g. environment & sustainability, ethics, team work, project management, finance, among others. These lists permit wide interpretation as to the breadth and depth of coverage of the various topics. Nor is there any indication of the relative importance of the various topics. These are issues because they results in a large amount of variability in the curricula of courses between institutions. For example some universities focus their course on finance (e.g. economics, accountancy, time value of money, cashflow, financial statements), and cover ethics in a single lecture. Others put the emphasis in totally different areas. Again, the amount of time devoted to the teaching of professional practice is highly variable. Consequently there is not the maturity of curriculum in this field as there is in the engineering sciences.

The jurisdiction under examination is New Zealand (NZ). The Institution of Professional Engineers NZ (IPENZ) is the only professional body for NZ and includes all practice areas. IPENZ implements the local accreditation processes [3], and largely follows the Washington Accord in its interpretation [4]. Consequently the various engineering universities in NZ all align their professional practice and engineering management curricula to the WA graduate attributes. Even so, they all do so in somewhat different ways, which are checked at the periodic accreditation visits. Any issues with the curriculum and teaching thereof have historically been merely minor, and no programme has lost accreditation because of material deficiencies in this area. Nonetheless there is ongoing interest between professional educators towards the harmonisation of curricula and the sharing of best practices in the teaching of professional practice and engineering management.

This paper helps address this problem by identifying the specific needs of professional engineering practitioners. In this context 'professional' refers primarily to the practitioner perspective, as opposed to that of the academics and professors. We report on an evidence-based approach to the determination of the professional practice and engineering management curriculum for undergraduates. Results from a large survey of practicing engineers were used to determine the relative importance of a variety of topics, singularly and in combinations of topics. From this we draw implications for teaching this subject. The results also permit a secondary question to be answered, which is to determine the context in which practitioners use communication skills.

2 Existing literature

The potential curriculum for professional practice is large, and it is difficult for educators to know what to include in a curriculum. What capabilities do students need to learn to be effective as practising professional engineers? What is the relative importance of the different topics? These are important questions for course design, and the literature identifies the many ways educators have approached this problem.

There is widespread acknowledgement among the professional educators of this field that the subject can be difficult to teach. 'Can the unteachable be taught?' is how the problem of teaching professional skills and management to engineers has sometimes been framed [5], thereby conveying the desperation that can exist in this area. That may be a somewhat extreme position, but even a positivist perspective would acknowledge that management and leaderships skills are areas needing further development for engineering [6].

There are several factors that contribute to the difficult of teaching engineering management. First, the subject can be disliked by students because of their predilection for mathematically tractable subjects rather than broader, more socially engaged, business roles [7] [8]. That can apply to university faculty too [9]. Academics teaching the subject may lack relevant experience from commercial practice, and thus find it difficult to contextualise the delivery [10].

In response to these challenges, innovative educators have taken a variety of imaginative approaches for teaching management to engineers. These typically seek to raise student engagement by embedding the student into the context, for example by simulating a creative environment, e.g. creating a game or simulation around the learning [11-14], or putting the student into a project-based environment [15-17].

Second, and the focus area of this paper, is the difficulty in knowing what to include in the curriculum. This curriculum issue is long-standing. Decades ago the need was anticipated for curriculum that would enable 'transition of the engineer from a technical specialist to an engineering management generalist who will constitute the large majority of future professional engineers' [18], and that need has never really abated [19]. It has been observed that undergraduate education primarily trained engineers for research & development (R&D) and academic positions, whereas most graduates went into management related areas with time [20]. The inadequacies of the curriculum in this regard have been pointed out [10, 21, 22], yet the criticism appears as fresh today as then. It has variously been asserted that the teaching of engineering management has been superficial, misguided, and lacking in relevance [23, 24].

The reality is that progress in defining a sufficient curriculum has been slow: much slower than in the engineering sciences. The profession continues to assert the relevance of soft-skills and engineering management, but it has been difficult to achieve a common expectation of what such a curriculum would contain. There are many potential topics that could be included, and it is difficult for lecturers to know which are the more important. Consequently the engineering management curriculum is generally based on local preferences and individual understanding of the issues.

High-level graduate attributes

The overall graduate attributes for an engineer are well-known, albeit at a broad abstract level, having emerged as an international consensus though the International Engineering Alliance [2]. Many countries, represented by their professional engineering institutions, are signatories to this Accord, and others are the in process of joining.

The Washington Accord covers the requirements for a professional engineering degree and is most relevant to the present paper. It specifies twelve graduate attributes [2], see Table 1. Two are focussed on the engineering sciences: fundamental engineering knowledge, and investigation. Three attributes are focussed on solving complex problems: problem analysis; design of solutions; modern tool usage. These also tacitly include the human dimension because 'complex' problems are defined as resulting 'from interactions between wide-ranging or conflicting technical, engineering or other issues'. The remaining seven attributes are of a professional nature: responsibilities to society (includes health & safety, legal, cultural); environment and sustainability; ethics; individual and team work; communication; project management and finance; life-long learning. In the past the following additional graduate competencies were explicitly required, but dropped from later versions: risk management, business practices, change management [25]. We mention this because our survey checked for the importance of these too. In some jurisdictions the Washington Accord requirements are re-packaged, and additional specifics and prescriptions are added in. These then become the national expectations against which accreditation is undertaken in that jurisdiction. A case is point is the USA, where the WA is reinterpreted into the ABET requirements [26]. However it is important to note that such local arrangements are derivative products and the Washington Accord remains the higher level reference standard. Other jurisdictions adopt the WA in its entirety, in which case the issue of potential misalignment does not arise.

		GRADUATE ATTRIBUTES for Washington Accord degree (paraphrased)
1.	**Engineering Knowledge :** Breadth and depth of education and type of knowledge, both theoretical and practical**.**	Knowledge: Have a systematic, theory-based understanding of the natural sciences, conceptually-based mathematics, mathematical methods, numerical analysis, statistics, computer and information science, engineering fundamentals, engineering specialist knowledge, and accepted practices. This knowledge is expected to cover the discipline as a whole (as opposed to being limited to a sub-discipline), and much of it is expected to be at the forefront of the discipline. Apply this knowledge to the analysis, modelling, and solution of complex engineering problems.
2.	**Problem Analysis:** Complexity of analysis	Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
3.	**Design/ development of solutions:** Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified	Design solutions for *complex* engineering problems and *design* systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
4.	**Investigation:** Breadth and depth of investigation and experimentation	Conduct investigations of complex problems using research-based knowledge (research literature) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
5.	**Modern Tool Usage:** Level of understanding of the appropriateness of the tool	Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities, with an understanding of the limitations.
6.	**The Engineer and Society:** Level of knowledge and responsibility	Comprehend the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
7.	**Environment and Sustainability:** Type of solutions.	Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.

8.	**Ethics:** Understanding and level of practice	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9.	**Individual and Team work :** Role in and diversity of team	Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
10.	**Communication :** Level of communication according to type of activities performed	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11.	**Project Management and Finance:** Level of management required for differing types of activity	Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12.	**Life long learning:** Preparation for and depth of continuing learning.	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Table 1: *Graduate competencies required for Engineers at the end of a 4yr study programme, as per the Washington Accord [2], paraphrased.*

Thus the Accord specifies attributes - knowledge and skills – that a student is required to have at graduation. It does not specify *how* the university has to go about creating those attributes. Universities are required to demonstrate that their curriculum does develop the required graduate attributes, and this is achieved through an accreditation process. Therefore to the extent that the graduate attributes include professional practice and engineering management, the accreditation process will ensure that that there is sufficient content in any one degree programme. In Australia the requirement is for at least 10% of course content in management related subjects [27]. However in many other jurisdictions the volume is not prescribed.

Curriculum topics

As this shows, an engineering degree is expected to contain a significant content to support professional practice and engineering management. However the Accords do not provide specific guidance for design of courses. For example, the Accord requires graduates to have some knowledge about 'finance', but does not say which of the many topics within that body of knowledge are more important. It is therefore left to the individual university and its lecturers to interpret and implement. Also, the Accord covers all the engineering disciplines, civil, mechanical, etc., and within those there are yet more specialised areas, but the Accord is unclear about the needs of specific industry [28].

Consequently each institution develops its own interpretation of what is required in the way of curriculum. There are many reports in the literature documenting what specific institutions decided to include in their curricula [16, 17, 29-32]. Generally these are reports of local teaching experiences and are therefore of a case-study nature. Typically these express statements by protagonists of current practice or future intent. Only very occasionally is there explicit evidence that the perceptions of the profession have informed these curriculum developments. It is also relevant to note that designing a new curriculum effectively imposes an 'intervention' in the educational experience of the students, yet the vast majority of cases in the literature have no measure of the efficacy of the intervention. Consequently while there is a profuse literature on the types of content various institutions have included, the real efficacy of those interventions is difficult to evaluate, and this means that the internal validity is uncertain. It is also difficult to determine which unknown situational variables might have led the institution to structure and deliver its curriculum in that particular way, and whether the experiences would reliably transfer to another institution. This means that the external validity is also uncertain. In most cases professional practice and engineering management are included as generic courses. Specialist undergraduate programmes for business engineering are comparably rare [33], which is understandable. Postgraduate programmes are common and there are numerous reports of the thinking behind these [30, 34-46]. However the postgraduate information is of limited value since the rationale for the choice of subjects taught is seldom explicit. Nor have many sought accreditation [47]. This is in common with postgraduate programmes generally and therefore not a criticism, but it does mean that the alignment between these postgraduate programmes and the needs of the profession has invariably not been tested. Consequently the structure of postgraduate programmes is not a reliable guide to the content of undergraduate degrees.

Finding empirical data in this area is problematic, and in approaching the literature one has to appraise whether the insights are personal to the protagonists, or backed by data. The majority of the literature in this area is solely based on the speculative insights of the protagonists who developed the course, and while it is interesting to read what others thought about the problem facing them, the problems with internal and external validity reduce the applicability of the results. It is not surprising that many of these reports are of a conference nature, which incidentally also makes them harder to procure. Therefore the most useful papers in the literature are those that are evidence-based. This component of the literature suggests the following engineering management skills are important:

- Adaptable problem-solving, creativity [11], critical thinking [48], decision making skills [48].
- Systems thinking approaches [49], integrative skills [50], a wide perspective of engineering [49], and a multidisciplinary approach [51-53].
- Engineering economics [54].
- Project management [48] [49],
- Quality [49],
- Marketing [55],
- Teamwork [48], leadership [6, 48].
- Ethical and social responsibility [56].
- Communication stands out as a particular need [15, 41, 47, 57, 58].

More recently there has been an effort to define an examination curriculum [59], the list of which includes market research, strategic planning and change management, product manufacturability, project management, scheduling, total quality, procurement, accounting, engineering economics, supply chain, marketing, organisational structures, leadership, human resources, standards, intellectual property, ethics, and liability.

Lists are useful, but still have several limitations.

1. Most of these lists are of the type 'we need more of xxx than is currently taught', but the difficulty is that the baseline is unknown, so the extent cannot be calibrated.
2. There is a problem of lack of specificity, since the lists cover a wide range of diverse topics. An associated problem is that the lists do not describe how deeply any one topic should be taught. For example, 'change management' is a vast topic in its own right, which could consume a whole course. It also has different meanings in various

areas, e.g. in product design & production it can refer to version control, whereas in business processes it involves changing the organisational culture and hence people's attitudes.

3. While the lists identify topics (e.g. 'communication'), they do not address the problem of how to contextualise the topics to students.
4. There is a lack of integration, in that the lists treat the topics as independent entities. Instead it is reasonable to expect that the topics could be clustered, but those associations are unknown. This is important because otherwise a curriculum risks being merely a disparate string of topics, when what we really want from a didactic perspective is to create in the graduate an integrated set of skills that can be applied to solve complex problems. Complex problems are those with many internal dependencies, and are not amenable to simplistic piecemeal solution approaches.

Most of the information in the literature is from the perspective of the academic institutions. There is a scarcity of empirical data from the engineering profession itself. Consequently there is a need for more empirical data from practising engineering, to help inform the design of the curriculum for professional practice and engineering management.

3 Purpose and approach

The purpose of the present work was to determine what practising professional engineers in industry felt were important engineering management topics to teach to students. This is worth doing because there is much confusion in the literature about which topics belong in the canon. There is a surfeit of opinion and a corresponding lack of objective evidence, and the voice of practising engineers is not heard often. Therefore this work aimed to undertake a broad inquiry to determine the relative importance of the many topics that people claim are important, rather than a specific analysis of individual topics. All the same, the results do permit a degree of more specific analysis, as will be shown for the 'communication' topic.

A questionnaire survey methodology was used, followed by statistical analysis. The survey addressed the entire New Zealand population of professional engineers, namely those who were members of IPENZ. The population was all the IPENZ Graduate Members, Professional Members, Technical Members, Associate Members and Fellows who were living in NZ and not-retired.

Two questions regarding engineering management were put to all members as part of an annual on-line salary survey run by IPENZ in 2009. The study was constrained to only two questions, because of concern about survey fatigue.

The survey was designed to assess the extent to which engineers were currently involved in engineering management. This was by self-report. No attempt was made to define 'engineering management' since (a) the concept is self-evident at least in the NZ context, being a recognised curriculum content at tertiary education and a recognised competency area for professional registration, and (b) we did not wish to frame respondents perceptions of 'engineering management' to our own constructs. Instead, a second question provided a list of engineering management topics and asked respondents to select those that they felt were important. So the definition of 'engineering management' was tacitly enumerated in the second question. The list of topics was determined as an aggregate of the various topics described in the Washington Accord and mentioned in the journal literature. Items that others had previously identified as part of the engineering management or professional practice competencies were included, with the exception of topics that were specific to single disciplines.

The questions were as follow:

Q17 To what extent does your current role involve engineering management?
Response categories: -1 = Did not answer; 1=Very Great Extent; 2=Great Extent; 3=Moderate Extent; 4=Slight Extent; 5=Not at all; 6=Do not know or not applicable

Q18 In your opinion, what engineering management topics (if any) should be taught to undergraduates? (Select as many as apply)
A large field of choices was given, see Table 2. Respondents were permitted to make multiple selections. However they were not asked to rank them, as this was potentially too difficult to achieve with any reliability, and could have added to the risk of ignoring the question. The actual performance of practitioners against the various management skills was not determined in this survey.

	Description	Abbreviation
1	Career planning	CareerPln
2	Business Processes in typical employer firms	BusProcess
3	Personality Styles	Persnlty
4	Development and management of Teams	TeamDev
5	Motivational Leadership	MotivLead
6	Professional relationship with society	Society
7	Cultural issues including Biculturalism, Multiculturalism and Treaty.	Cultural
8	Health and safety requirements.	H&S
9	Professional associations including IPENZ.	ProfMemb
10	Ethics.	Ethic
11	Environment and Sustainability including Resource Management Act	Enviro
12	Project planning	PM_Plan
13	Project monitoring	PM_Monit
14	Communication including report writing.	Communic
15	Engineering relevant Finance and project costing methods	ProjCost
16	Accounting principles	Account
17	Economics	Econ
18	Budgets, Profit and Loss Statement	Budget
19	NPV, Capital, and Depreciation	NPV
20	Product Life cycle, R&D stages, Innovation, Creativity	Innov
21	Risk Management, including SAA/SNZ HB	RiskMan

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22	Change Management	ChangeMan
23	Engineering relevant law, Contracts, Product liability	Law
24	Quality, Organisational Systems	Quality
25	Product certification	PrdCert
26	Procurement.	Procure
27	Contract administration.	Contract
28	Human Resource Management	HR
29	Organisational Structure	OrgStr
30	Knowledge Management, NDA, IP Protection	KM
31	Marketing	Market
32	Entrepreneurship, organisation formation and growth	Entrep
33	Strategy, External forces, Mission, Vision, Governance.	Strategy

Table 2: Response categories for Q18 in survey

While these were the only two questions that were asked, the analysis also had access to data from other questions that were part of the survey, including: qualification, years since graduation, practice area, job points, and demographics. Job points is an IPENZ measure of job complexity and is determined by aggregating responses to several questions. Included therein are questions about the level of responsibility for decision-making by the engineer. It therefore broadly measures complexity in professional practice. This additional data permitted a much deeper analysis than the two engineering management questions on their own.

The number of responses received was 2276, representing a 38% return. This is a high response rate.

Statistical methods were used to summarise the data and extract implications. One such method was the determination of summaries of frequencies. These are based on the frequency with which a response was given. In some cases the results were categorised by variables such as practice area. In addition a data-mining method called association rules analysis (ARA) was also used, to explore the data and seek out hidden relationships in a retrospective manner. The latter is an uncommon research method, with no known instances of it being applied to this type of situation. A brief summary of ARA is provided below. The software tool used was Statistica.

4 Results

These results are for the entire cohort of engineers, and include a variety of disciplines (civil, mechanical, electrical, electronic, etc.) and practice areas. The results are presented for single topics, then for the more complex situation of combinations of topics, and finally for the 'communication' topic.

4.1 Topics by simple frequency

The results are shown in Figure 1, ranked by the percent support for each topic.

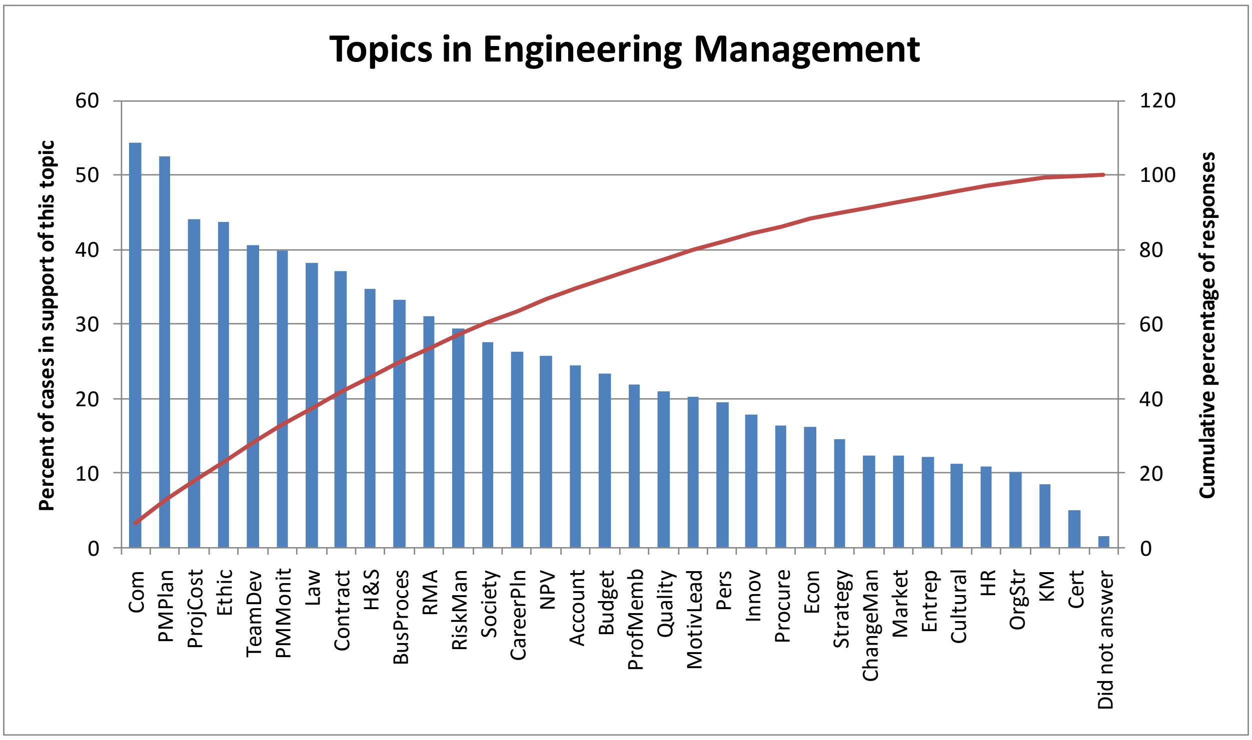

Figure 1: Support for various topics. Engineers felt that the most important topics were communication, closely followed by project planning, and then others as shown. For interpretation of the labels see Table 2.

This diagram shows several features. First, it identifies the most important topic as being COMMUNICATION, followed by PROJECT PLANNING. For a slightly wider set, all with at least 40% support, add Project Costing, Ethics, and Team Development. It also shows the relative ranking of topics by their support. This is important from the lecturing perspective, as course designers must make difficult decisions on how much time to allocate to topics.

There is no scree feature (sharp change in support) visible in this plot, so there is no easy demarcation between topics that are relevant vs. irrelevant. Instead almost every topic offered was considered important by the profession, and nothing is eliminated outright. However there is a way to determine cut-off points, which is to use the cumulative line. Thus a portfolio of topics that covers 50% of the responses is: Communications, Project Planning, Project Costing, Ethics, Team Development, Project monitoring, Law, Contract, Health and Safety, and Business processes. For a 75% portfolio add: Natural Resource management, Risk Management, Society, Career Planning, present value, Accounting, Budgets, and Professional Membership.

The analysis to this point is for single discrete topics. However this is a simplistic view as combinations of topics are sometimes more important than discrete topics, as the next analysis shows.

4.2 Combinations of Topics

The more-detailed ARA showed that compound topics were often more important than individual topics on their own. Those results are shown in Appendix A, and summarised at a high level here. The list has been structured somewhat arbitrarily at 40%, 30%, 20% and 15% thresholds for support:

1. The top two EM topics from the perspective of engineering practitioners remain communication and project planning with support of 49% and 47% respectively.
2. The second tier of topics, all of which had at least 30% support, are (in descending order):
    - Project Costing;
    - Ethics;
    - combination of Project Planning and Communication;
    - Team Development;
    - Project Monitoring;
    - Law;
    - Contract;
    - combination of Project Planning and Monitoring;
    - Health and Safety;
    - combination of Project Planning and Project Costing;
    - combination of Project Costing and Communication;
    - Business operating processes.

It is notable that finance and engineering economics do not feature in the top two tiers. This was somewhat surprising, given the high emphasis that many educators place on these topics. The third and fourth tier topics and combinations are shown in Appendix A and left for inspection. Thus it is possible to define a curriculum to various degrees of extensiveness, depending on how completely one wishes to cover the subject.

The presence of the combinations is potentially useful information for teaching purposes: it shows that there is commonality in how practicing engineers think of these topic clusters. Consequently it may be worth trying to teach them in similar contexts.

4.3 What does the communication topic comprise?

Communication emerges as the single most important topic. It encompasses many media (written, spoken), and the survey did not identify its specific subtopics. Unfortunately, it tends to be a subject that is difficult to teach [58] [60]. There are many voices in the literature attesting to the importance of communication skills for engineers [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72]. In some cases specific sub-sets of communication are addressed, such as collaboration [73], conflict resolution [74], or cross-cultural skills [75] [76]. However the limitation observed previously made applies: these report on university centric perspectives or intended changes to the content or way that communication skills are taught to students. In some cases, though rarely, the efficacy of the intervention has been validated. Examples include where student experiences have been evaluated, e.g. in capstone projects [77]. There appears to be no research in communication as grounded in the needs of the profession itself.

Consequently it would be useful to identify from the profession itself (1) which parts of the larger body of communication to teach, (2) how to integrate the topic together and contextualise it for engineering, and (3) how to motivate students to want to excel at it. While the survey was not designed *a priori* to answer those questions, it is possible to extract some partial conclusions from the data.

The ARA method was used to extract all the topics associated with communication, as shown in Appendix A Table A3. In this analysis communication is the *body*, and the *head* identifies the associated topics. The table is ranked from greatest to least confidence, i.e. the association at the top are the more important. The table shown is only the communication sub-set of a larger table of rules. This table identifies the other topics close to communication. For example: Of those who identified communication as important, 75% also felt that project planning was important (rule 57). The *head* therefore identifies the context. Note that sometimes there are multiple heads, e.g. project planning and monitoring (rule 69), and that these may have greater confidence than single topics. Thus the combinations can be more important than the individual items. Next we categorised these contexts into clusters. We identified two main contexts:

1. Primary association: Communication is applied primarily in the context of project management (rules 57, 58, 62, 69, 66, 68, 67, 72, 70). Statistically, this context dominates for confidence, and has the most rules in support.

2. Secondary association: The second tier contexts for communication emerge as law and contract (rules 59, 61, 68, 67, 71), ethics (rules 65, 70), environment (rule 60), team development (rule 56), health and safety (rule 64), and risk management (rule 63).

Several implications emerge. First, these contexts can have very different communication requirements. For example health & safety involves training, warning notices, instructions, safety culture, and compliance documentation, whereas team development involves roles and conflict. Thus communication emerges as a context-specific construct.

Second, some of these areas already specifically include communication within their body of knowledge. This is specifically for risk management and project management [78, 79]. Those might be useful starting points for setting a communication syllabus for engineering. Or at very least the context in which communication is taught could be consistent with application into those areas.

Use of ARA therefore partially answers question (1): which parts of the larger body of communication to teach. The answer is: primarily those parts of communication that inform project management, and secondarily law, contract, ethics, environment, teams, health & safety, and risk management.

The ARA also determines the reciprocal associations, see Appendix Table A4. In this analysis communication is the head, and the body identifies the associated topics. As an example, of those engineers who identified project planning, costing, and monitoring as important, 88%

also selected communication (rule 148). The interpretation is that communication is essential if an engineer is going to be doing those three project activities. Thus an additional set of associations are uncovered from the other perspective. Most of these are common, e.g. rules 73 and 148, but note that the table emphasises the compound topics more, and we interpret these as practice areas where communication is particularly important. On this list the compound topics are more important (greater % confidence) than single topics. For example project planning and ethics (rule 127) are more important than ethics on its own (rule 102). The presence of compound topics indicates complexity to the problem being addressed, i.e. engineers are integrating several skills in their practice. They are not just communicating ethically, but doing so along with project planning.

Specifically we identify two main categories of responses as:

1. Project management: whenever the project management activities are involved, in whatever combinations, there is a high chance that communication will also be required.

2. Miscellaneous areas: Activities such as environmental sustainability, law, contracts, risk management, health & safety, ethics, and team development, all tended to also be associated with communication.

Association rules determine association, not causality. However within that limitation we interpret the above results to give a partial answer to question (2): how to contextualise 'communication' to engineering students. The answer is: show them that if they are to be successful at real engineering projects then they need to understand communication, because it's almost always needed in the project situation, and they are likely to be doing a lot of project work.

Regarding the other part of Question (2): how to integrate the selected components of communication so that they make for coherence, there are no complete answers yet. However there are frameworks in other disciplines that accomplish similar objectives. In particular the Project Management Institute (PMI) has developed a 'Body of Knowledge (PMBOK)'® [78] that describes the activities that a professional project manager will generally have to consider. The first four knowledge areas (project integration, scope, time and cost) are core to project management (PM), whereas the others (cost, quality, human resources, communications, risk, and procurement) are from other disciplines. While this list does not cover all the topics required for the development of a Professional Engineer, it is notable just how much it *does* cover. If the only soft skills that undergraduate engineers were taught were the nine project knowledge areas, then that would be a reasonably good coverage. It is also relevant to note that many engineering graduates are involved in project-based work. Naturally those graduates who move into general management are likely to need a wider set of management skills. We have not addressed Question (3): how to motivate students to want to excel at 'communication'. We leave that for future work.

5 Discussion

5.1 Originality

This paper makes a contribution in several ways. First, it is one of only a few large-scale surveys of practising engineers to have explored the soft-skill attributes. Second, it makes a didactic contribution of providing a ranked list of topics which can be used for designing the curriculum and prioritising teaching effort, which has not previously existed in the literature. Interestingly, it shows that combinations of topics are sometimes more important than individual topics, and this too is a new insight. Third, it makes the methodological contribution of showing how the specific statistical method of association rules analysis may be used to extract insights about the EM curriculum. Fourth, it identifies the context in which Communication is important for engineers, which is primarily project management. Fifth, it identifies new interactions between the graduate attributes for professional engineers and the bodies of management in other areas like project management. This is important as many engineering ventures are conducted as projects, and it is useful to know which parts of project management thinking are particularly valuable in the broader setting of engineering management: project planning as it turns out.

5.2 Implications

Implications for curriculum development
The results readily suggest implications for setting curriculum. The most important topics are identified as Communications, Project Planning, Project Costing, Ethics, Team Development, Project monitoring, Law, Contract, Health and Safety, and Business processes. One can reasonably expect that a general engineering management course would at least cover those topics, though there may be discipline-specific variability. Furthermore, there were many cases where combinations of topics were more important than single topics. We interpret this as a need to understand and apply the topics in integrated ways rather than disjoint skills. This is consistent with the concept of engineering involving 'complex' tasks, as described in the Washington Accord. Thus an engineering programme that primarily interpreted engineering management as financial management and economics would be deficient according to the findings here.

It would have been convenient if the research had discovered that certain topics were essential, and others not. A limited set of topics would have permitted focussed attention for curriculum, and indeed accreditation. However this research did not find any such curtailed list. This is consistent with the observation that engineering involves complex problem-solving rather than simple deterministic approaches. As a tentative recommendation we suggest that any topic that has less than 15% support in Figure 1 (or Table A1) is probably not relevant to a mandatory generic engineering management course.

A particularly far-reaching implication is the resourcing of delivery material. Existing textbooks are poorly focused on the topics identified here and more specifically targeted textbooks may be warranted. In many cases the focus is more on management than the engineering profession, which means that some topics are well-covered, but others not. For example, ethics and health & safety seldom feature in management textbooks. However it should not be assumed that every topic needs to be taught in a specialised EM course:

instead it may be possible to embed the learning elsewhere, including in other courses and in work experience [80].

Implications for Graduate competencies and accreditation
The Accords define a set of graduate competencies: knowledge and skills that students should have at graduation. These competencies represent the assessment of the engineering professional bodies, typically the aggregation of expert opinion through a committee process. The data presented here are from a different approach altogether, based on industry practitioner experience.

It is therefore possible to compare the topics across the Accords and the survey. This is potentially useful to determine level of support for the Accords, and to check for gaps. All the attributes of the Washington Accord [81] are identifiable in Table A1. However there are some other topics with higher frequency, which are not in the Accord. For example 'team development' and 'business processes' have high importance to the profession, and should probably be included in the graduate attributes.

While the survey only extended to New Zealand engineers, the results are likely to have relevance to other countries. This is because the IEM framework results in the engineering practices being comparable in the member countries. These include New Zealand, Australia, South Africa, Singapore and many countries in Europe and North America. Multi-national engineering consultancies exist across those countries, and there is a high level of international mobility within the engineering profession. So it is likely that the perspectives of the New Zealand engineers surveyed here are broadly representative of engineers in the IEM framework. In which case the implications for teaching practices, as identified above, could be generally relevant to other countries.

Professional development for Professional Engineers
Those practising Engineers who have a mind to professional development in the engineering management areas would be advised to focus their development on communication and project planning, as the survey results underline the importance of these topics to practising engineers. However these are only the basics, and engineers need to recognise that they will need to further develop their management skills from whatever based they obtained as undergraduates, by active professional development. The ability to apply multiple soft skills in an integrative manner is strongly supported by the data, and thus we presume that learning how to do this would also be advantageous.

5.3 Limitations of this research

There are several limitations to this work. First, the actual performance of graduates against the topics was not determined. It could be that graduates are already excellent at the topics, or they could be very bad: there is no way of knowing from these data.

Second, while the sample size and return rate were excellent for surveys, where 15% return is usually considered acceptable, the population of IPENZ members is skewed towards the civil and mechanical practice areas. The survey sample was from those engineers who have membership of IPENZ, but there are also other engineers who are not members of that body and therefore not sampled. Thus a different set of skills may be necessary for engineers who no longer maintain a professional membership. However this last point is a minor consideration as the focus of the present work is on identifying the skills needed by practising professional engineers, not those who have moved beyond the profession.

Third, the results are limited to identifying the relative importance of the various topics. While that partly addresses the question of what to include in a syllabus, it does not answer the question of how best to teach the material. For that a different design of research would be needed, one based on qualitative research methods.

5.4 Implications for further research

The present work aimed to undertake a broad inquiry to determine the relative importance of the many topics that people claim are important for engineers generally, rather than a specific analysis of individual topics. All the same, the results do permit a degree of more specific analysis, as was shown for the 'communication' topic. That it was possible to analyse the 'communication' topic this way was due to the statistical power (large survey dataset) and the novel application of a particular statistical method (association rules). It was not known beforehand which topics would be more or less important. For this reason and also to keep the survey simple and focussed on the broad picture, we did not ask detailed questions of the various individual topics. The results have now revealed the importance of the various topics. This presents an opportunity for future researchers to undertake more penetrating analyses of the various individual topics. However, there is also a warning for future researchers, since the current results show that *combinations* of topics can be more important that individual topics on their own, i.e. there is a degree of correlation or contextualisation to the topics. The information presented here, including the detailed statistical tables in the appendix, may help future researchers. They may be able to compare their results against those published here, and the contrasts and similarities could open new insights.

There are several strands of further research that could be followed:

- What do Professional Engineers understand as important within 'Communication', and how can that be included into curriculum? This is the most pressing. We have included some analysis here, but evidently there is more work to be done.
- Determine implications for continuous professional development of engineers.
- Find out the needs of specific engineering disciplines regarding engineering management topics, i.e. which topics are most important and to what depth they need to be taught.
- Determine how well-prepared graduates actually are, i.e. engineering management competence.
- Clarify what Engineers understand as important within 'project planning'. Is it Work-breakdown structure? Project costing? Gantt chart? Competent use of software? Workloads? Supporting Documents?
- Extend the research to other countries, and see to what extent the results are nationally-specific and why.
- Conduct a longitudinal study to determine whether the need for engineering management changes with career, when, and why. Explore how engineers' ranking of the importance of management topics changes over the span of their careers.

Those who have moved into management roles, for example, may see finance and business strategy as of increasing importance.

- Compare teaching practices across several universities in a benchmarking study, and seek to identify best practices.
- For some engineers their career will take them out of engineering: they no longer apply their skills 'in' engineering but work 'with' their engineering skills in other settings. Further research could be valuable in exploring the skills needed by engineers for those non-engineering roles. For example, topics like strategy had relatively low support in this survey, but it may be that they are nonetheless important to the wider engineering population.

Finally, it is important to realise that there are at least three stakeholder groups who have an interest in the engineering management and professional practice canon. The first are the educational professionals. Their view tends to dominate the literature. The second is the engineering profession, which is less often heard in the literature, but exerts its influence through the accreditation process. The third is the student perspective. Relevant research questions for the latter group might be: what do they expect of their courses on this subject, what aspects of a professional engineering career do they perceive as particularly valuable to themselves, what motivates them about the professional practice subject? The present work has taken the practitioner perspective for its data, and used this to infer implications for educationalists. It has only peripherally addressed some of the student perspectives. There are many future research opportunities to examine this three-way integration.

6 Conclusions

The purpose of this project was to determine the curriculum topics for undergraduate education in engineering management. Practising engineers were surveyed. The overall results show that Communication and Project planning were the most important. However a large number of topics were identified as important to some extent: there was no clear cut-off observed for unimportant topics. For example the 50% portfolio is Communications, Project Planning, Project Costing, Ethics, Team Development, Project monitoring, Law, Contract, Health and Safety, and Business processes. Furthermore, there were many cases where combinations of topics were more important than single topics. We interpret this as a need of practitioners to understand and apply the topics in integrated ways rather than discrete disjoint skills. The results also identify the contexts for the various topics. It is shown that Communication is primarily associated with project management, and its secondary contexts are in law and contract, ethics, environment , team development, health and safety, and risk management.

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Appendix A: Statistical tables

The primary purpose of providing the detailed statistical tables is to provide comparative data for future studies and meta-analyses.

Table A1 shows the level of statistical support found for each topic, or combinations of topics. This table has data that may be useful for educationalists. The support can be understood to represent the proportion of engineers who believed that this topic, or combination of topics, was important. Hence higher support indicates a more important topic or set of topics. The results have been categorised by thresholds of 40%, 30%, and 20%. However these point are necessarily somewhat arbitrary. The table provides the data so that Readers can apply their own different selection criteria should they wish.

Table A2 shows the Correlation matrix for the various topics. The data may be useful to future researchers. primarily

Tables A3 and A4 provides the specific association rules for ‘communication’, first as the body and then as the head. The data are provided in support of the conclusions reached in the paper, and to support future research into this important topic.

Levels of support for topics and groups of topics

Rule number	Frequent itemsets	Support(%)
12	Communic	48.92308
4	PM_Plan	47.34066
5	ProjCost	39.6044
22	Ethic	39.2967
42	PM_Plan, Communic	36.57143
3	TeamDev	36.48352
16	PM_Monit	35.86813
8	Law	34.41758
14	Contract	33.45055
45	PM_Plan, PM_Monit	32.65934
21	H&S	31.34066
36	PM_Plan, ProjCost	30.68132
53	ProjCost, Communic	30.59341
2	BusProces	30.02198
80	Communic, PM_Monit	28.83516
11	Enviro	27.95604
119	PM_Plan, Communic, PM_Monit	27.25275
63	Law, Communic	27.07692
84	Communic, Ethic	26.9011
44	PM_Plan, Contract	26.54945
20	RiskMan	26.50549
79	Communic, Contract	26.15385
103	PM_Plan, ProjCost, Communic	25.97802
38	PM_Plan, Law	25.89011
49	PM_Plan, Ethic	25.75824
56	ProjCost, PM_Monit	24.96703
10	Society	24.74725
51	ProjCost, Law	24.21978
105	PM_Plan, ProjCost, PM_Monit	23.73626
18	CareerPln	23.69231
31	TeamDev, Communic	23.38462
28	TeamDev, PM_Plan	23.2967
13	NPV	23.16484
55	ProjCost, Contract	22.9011
72	Enviro, Communic	22.50549
85	Contract, PM_Monit	22.32967
118	PM_Plan, Communic, Contract	22.32967
109	PM_Plan, Law, Communic	22.28571
83	Communic, H&S	22.06593
60	ProjCost, Ethic	22.02198
6	Account	21.97802
64	Law, Contract	21.75824
134	ProjCost, Communic, PM_Monit	21.75824
122	PM_Plan, Communic, Ethic	21.71429
41	PM_Plan, Enviro	21.62637
65	Law, PM_Monit	21.14286
123	PM_Plan, Contract, PM_Monit	21.14286
48	PM_Plan, H&S	21.0989

Rule number	Frequent itemsets	Support(%)
19	Budget	21.05495
160	PM_Plan, ProjCost, Communic, PM_Monit	20.92308
68	Law, Ethic	20.87912
35	TeamDev, Ethic	20.74725
47	PM_Plan, RiskMan	20.74725
128	ProjCost, Law, Communic	20.65934
93	H&S, Ethic	20.52747
82	Communic, RiskMan	20.35165
101	PM_Plan, ProjCost, Law	20.35165
111	PM_Plan, Law, PM_Monit	20.08791
104	PM_Plan, ProjCost, Contract	20.04396
29	TeamDev, ProjCost	20
91	PM_Monit, Ethic	19.78022
15	ProfMemb	19.73626
52	ProjCost, Enviro	19.56044
96	TeamDev, PM_Plan, Communic	19.56044
133	ProjCost, Communic, Contract	19.34066
77	Enviro, Ethic	19.20879
59	ProjCost, H&S	19.12088
148	Communic, Contract, PM_Monit	19.12088
88	Contract, Ethic	18.98901
127	PM_Plan, PM_Monit, Ethic	18.94505
9	Quality	18.9011
108	PM_Plan, ProjCost, Ethic	18.9011
114	PM_Plan, Enviro, Communic	18.9011
137	ProjCost, Communic, Ethic	18.76923
33	TeamDev, PM_Monit	18.72527
142	Law, Communic, PM_Monit	18.59341
26	BusProces, Communic	18.50549
58	ProjCost, RiskMan	18.50549
110	PM_Plan, Law, Contract	18.50549
141	Law, Communic, Contract	18.50549
167	PM_Plan, Communic, Contract, PM_Monit	18.46154
78	Communic, NPV	18.28571
155	PM_Plan, ProjCost, Law, Communic	18.28571
24	BusProces, PM_Plan	18.06593
66	Law, RiskMan	18.06593
71	Society, Ethic	17.97802
62	Law, Enviro	17.93407
121	PM_Plan, Communic, H&S	17.93407
164	PM_Plan, Law, Communic, PM_Monit	17.89011
43	PM_Plan, NPV	17.75824
144	Law, Communic, Ethic	17.75824
90	PM_Monit, H&S	17.71429
97	TeamDev, PM_Plan, PM_Monit	17.67033
17	Persnlty	17.58242
67	Law, H&S	17.58242
120	PM_Plan, Communic, RiskMan	17.58242
159	PM_Plan, ProjCost, Communic, Contract	17.53846
61	Account, Communic	17.49451
25	BusProces, ProjCost	17.40659
87	Contract, H&S	17.40659

Rule number	Frequent itemsets	Support(%)
151	Communic, PM_Monit, Ethic	17.27473
95	TeamDev, PM_Plan, ProjCost	17.23077
113	PM_Plan, Law, Ethic	17.23077
138	ProjCost, Contract, PM_Monit	17.23077
54	ProjCost, NPV	17.18681
98	TeamDev, ProjCost, Communic	17.18681
30	TeamDev, Law	17.0989
32	TeamDev, Contract	17.0989
70	Society, Communic	17.0989
74	Enviro, PM_Monit	17.05495
129	ProjCost, Law, Contract	16.96703
89	PM_Monit, RiskMan	16.87912
130	ProjCost, Law, PM_Monit	16.87912
132	ProjCost, Enviro, Communic	16.87912
92	RiskMan, Ethic	16.83516
102	PM_Plan, ProjCost, Enviro	16.83516
27	BusProces, Ethic	16.79121
126	PM_Plan, PM_Monit, H&S	16.74725
162	PM_Plan, ProjCost, Contract, PM_Monit	16.74725
168	PM_Plan, Communic, PM_Monit, Ethic	16.74725
37	PM_Plan, Account	16.7033
161	PM_Plan, ProjCost, Communic, Ethic	16.7033
73	Enviro, Contract	16.65934
107	PM_Plan, ProjCost, H&S	16.61538
34	TeamDev, H&S	16.52747
86	Contract, RiskMan	16.52747
147	Enviro, Communic, Ethic	16.48352
157	PM_Plan, ProjCost, Law, PM_Monit	16.43956
136	ProjCost, Communic, H&S	16.3956
163	PM_Plan, Law, Communic, Contract	16.3956
115	PM_Plan, Enviro, PM_Monit	16.35165
124	PM_Plan, Contract, Ethic	16.35165
81	Communic, Budget	16.30769
145	Law, Contract, PM_Monit	16.13187
125	PM_Plan, PM_Monit, RiskMan	16.08791
149	Communic, Contract, Ethic	16.08791
7	Innov	16.04396
50	ProjCost, Account	16
106	PM_Plan, ProjCost, RiskMan	16
46	PM_Plan, Budget	15.91209
76	Enviro, H&S	15.91209
99	TeamDev, Communic, PM_Monit	15.91209
116	PM_Plan, Enviro, Ethic	15.91209
131	ProjCost, Law, Ethic	15.82418
57	ProjCost, Budget	15.78022
69	Quality, Communic	15.78022
23	BusProces, TeamDev	15.73626
140	Law, Enviro, Communic	15.73626
39	PM_Plan, Quality	15.69231
40	PM_Plan, Society	15.64835
135	ProjCost, Communic, RiskMan	15.56044
146	Enviro, Communic, PM_Monit	15.47253

Rule number	Frequent itemsets	Support(%)
170	ProjCost, Law, Communic, PM_Monit	15.47253
94	BusProces, PM_Plan, Communic	15.42857
112	PM_Plan, Law, RiskMan	15.42857
166	PM_Plan, Law, Contract, PM_Monit	15.42857
171	ProjCost, Communic, Contract, PM_Monit	15.42857
117	PM_Plan, Communic, NPV	15.38462
152	Communic, H&S, Ethic	15.38462
153	TeamDev, PM_Plan, ProjCost, Communic	15.38462
156	PM_Plan, ProjCost, Law, Contract	15.34066
139	ProjCost, PM_Monit, Ethic	15.25275
154	TeamDev, PM_Plan, Communic, PM_Monit	15.25275
150	Communic, PM_Monit, H&S	15.20879
169	ProjCost, Law, Communic, Contract	15.20879
172	PM_Plan, ProjCost, Law, Communic, PM_Monit	15.16484
75	Enviro, RiskMan	15.12088
165	PM_Plan, Law, Communic, Ethic	15.12088
173	PM_Plan, ProjCost, Communic, Contract, PM_Monit	15.12088
100	TeamDev, Communic, Ethic	15.07692
158	PM_Plan, ProjCost, Enviro, Communic	15.07692
143	Law, Communic, H&S	15.03297

Table A1: ARA results for support greater than 15%. Both single and compound topics are shown. The table is ranked by support level and the demarcations set at 40%, 30%, 20%, and 15%. Topics with less than 15% support are not shown here at all.

Correlation matrix

Column		Col. 4 Account	Col. 5 Budget	Col. 6 BusProces	Col. 7 CareerPln	Col. 8 PrdCert	Col. 9 ChangeMan	Col. 10 Communic	Col. 11 Contract	Col. 12 Cultural
4	Account	1.00	0.47	0.21	0.15	0.20	0.27	0.33	0.31	0.17
5	Budget	0.47	1.00	0.20	0.16	0.21	0.30	0.29	0.31	0.19
6	BusProces	0.21	0.20	1.00	0.19	0.12	0.15	0.17	0.14	0.10
7	CareerPln	0.15	0.16	0.19	1.00	0.11	0.14	0.15	0.11	0.20
8	PrdCert	0.20	0.21	0.12	0.11	1.00	0.25	0.15	0.17	0.21
9	Change Man	0.27	0.30	0.15	0.14	0.25	1.00	0.20	0.22	0.18
10	Communic	0.33	0.29	0.17	0.15	0.15	0.20	1.00	0.42	0.17
11	Contract	0.31	0.31	0.14	0.11	0.17	0.22	0.42	1.00	0.16
12	Cultural	0.17	0.19	0.10	0.20	0.21	0.18	0.17	0.16	1.00
13	Econ	0.42	0.36	0.16	0.14	0.21	0.23	0.26	0.23	0.21
14	Entrep	0.26	0.28	0.15	0.17	0.23	0.24	0.20	0.21	0.20
15	Ethics	0.25	0.22	0.22	0.24	0.13	0.17	0.31	0.25	0.30
16	H&S	0.20	0.24	0.23	0.21	0.16	0.19	0.29	0.32	0.26
17	HR	0.27	0.33	0.15	0.12	0.27	0.30	0.21	0.24	0.22
18	Innov	0.30	0.33	0.17	0.16	0.22	0.27	0.29	0.25	0.22
19	KM	0.27	0.29	0.18	0.17	0.31	0.33	0.20	0.21	0.28
20	Law	0.33	0.33	0.18	0.15	0.19	0.25	0.43	0.46	0.22
21	Market	0.29	0.32	0.18	0.17	0.23	0.28	0.24	0.24	0.20
22	MotivLead	0.23	0.23	0.19	0.21	0.19	0.26	0.12	0.12	0.21
23	NPV	0.39	0.48	0.18	0.13	0.16	0.29	0.33	0.32	0.18
24	OrgStr	0.27	0.27	0.19	0.18	0.25	0.28	0.22	0.29	0.20
25	Persnlty	0.17	0.17	0.22	0.23	0.17	0.21	0.14	0.10	0.25
26	PM_Monit	0.29	0.33	0.18	0.15	0.18	0.25	0.47	0.46	0.13
27	PM_Plan	0.30	0.29	0.17	0.15	0.16	0.23	0.54	0.45	0.14
28	Procure	0.24	0.33	0.15	0.15	0.26	0.27	0.27	0.39	0.17
29	ProfMemb	0.19	0.20	0.20	0.32	0.21	0.14	0.25	0.19	0.28
30	ProjCost	0.36	0.37	0.25	0.12	0.19	0.24	0.46	0.42	0.18
31	Quality	0.27	0.32	0.19	0.16	0.26	0.30	0.33	0.34	0.19
32	RiskMan	0.28	0.30	0.16	0.15	0.17	0.28	0.33	0.37	0.22

33	Enviro	0.27	0.27	0.16	0.17	0.14	0.21	0.39	0.35	0.32
34	Society	0.17	0.15	0.18	0.28	0.17	0.11	0.23	0.14	0.35
35	Strategy	0.26	0.27	0.17	0.16	0.23	0.32	0.20	0.19	0.22
36	TeamDev	0.20	0.21	0.22	0.21	0.14	0.23	0.23	0.22	0.16

Column		Col. 13 Econ	Col. 14 Entrep	Col. 15 Ethics	Col. 16 H&S	Col. 17 HR	Col. 18 Innov	Col. 19 KM	Col. 20 Law	Col. 21 Market
4	Account	0.42	0.26	0.25	0.20	0.27	0.30	0.27	0.33	0.29
5	Budget	0.36	0.28	0.22	0.24	0.33	0.33	0.29	0.33	0.32
6	BusProces	0.16	0.15	0.22	0.23	0.15	0.17	0.18	0.18	0.18
7	CareerPln	0.14	0.17	0.24	0.21	0.12	0.16	0.17	0.15	0.17
8	PrdCert	0.21	0.23	0.13	0.16	0.27	0.22	0.31	0.19	0.23
9	ChangeMan	0.23	0.24	0.17	0.19	0.30	0.27	0.33	0.25	0.28
10	Communic	0.26	0.20	0.31	0.29	0.21	0.29	0.20	0.43	0.24
11	Contract	0.23	0.21	0.25	0.32	0.24	0.25	0.21	0.46	0.24
12	Cultural	0.21	0.20	0.30	0.26	0.22	0.22	0.28	0.22	0.20
13	Econ	1.00	0.29	0.20	0.16	0.21	0.31	0.25	0.27	0.28
14	Entrep	0.29	1.00	0.18	0.08	0.30	0.32	0.37	0.23	0.41
15	Ethics	0.20	0.18	1.00	0.36	0.19	0.26	0.21	0.32	0.18
16	H&S	0.16	0.08	0.36	1.00	0.20	0.21	0.19	0.31	0.16
17	HR	0.21	0.30	0.19	0.20	1.00	0.26	0.30	0.21	0.35
18	Innov	0.31	0.32	0.26	0.21	0.26	1.00	0.37	0.31	0.30
19	KM	0.25	0.37	0.21	0.19	0.30	0.37	1.00	0.27	0.35
20	Law	0.27	0.23	0.32	0.31	0.21	0.31	0.27	1.00	0.24
21	Market	0.28	0.41	0.18	0.16	0.35	0.30	0.35	0.24	1.00
22	MotivLead	0.19	0.24	0.20	0.17	0.27	0.18	0.17	0.13	0.20
23	NPV	0.35	0.30	0.27	0.27	0.24	0.42	0.27	0.34	0.27
24	OrgStr	0.24	0.31	0.21	0.16	0.41	0.28	0.34	0.24	0.33
25	Persnlty	0.20	0.19	0.23	0.19	0.20	0.18	0.18	0.11	0.19
26	PM_Monit	0.23	0.19	0.24	0.29	0.22	0.27	0.23	0.39	0.23
27	PM_Plan	0.25	0.19	0.29	0.27	0.21	0.30	0.22	0.40	0.22
28	Procure	0.27	0.23	0.17	0.23	0.29	0.27	0.23	0.31	0.25
29	ProfMemb	0.17	0.19	0.34	0.30	0.20	0.22	0.21	0.21	0.19
30	ProjCost	0.30	0.22	0.27	0.30	0.21	0.34	0.24	0.46	0.24
31	Quality	0.21	0.26	0.24	0.30	0.28	0.32	0.27	0.37	0.31
32	RiskMan	0.28	0.20	0.30	0.32	0.26	0.35	0.25	0.43	0.20

Column		Col. 22 Motiv Lead	Col. 23 NPV	Col. 24 Org Str	Col. 25 Persnlty	Col. 26 PM_Monit	Col. 27 PM_Plan	Col. 28 Procure	Col. 29 Prof Memb	Col. 30 Proj Cost
4	Account	0.23	0.39	0.27	0.17	0.29	0.30	0.24	0.19	0.36
5	Budget	0.23	0.48	0.27	0.17	0.33	0.29	0.33	0.20	0.37
6	BusProces	0.19	0.18	0.19	0.22	0.18	0.17	0.15	0.20	0.25
7	CareerPln	0.21	0.13	0.18	0.23	0.15	0.15	0.15	0.32	0.12
8	PrdCert	0.19	0.16	0.25	0.17	0.18	0.16	0.26	0.21	0.19
9	ChangeMan	0.26	0.29	0.28	0.21	0.25	0.23	0.27	0.14	0.24
10	Communic	0.12	0.33	0.22	0.14	0.47	0.54	0.27	0.25	0.46
11	Contract	0.12	0.32	0.29	0.10	0.46	0.45	0.39	0.19	0.42
12	Cultural	0.21	0.18	0.20	0.25	0.13	0.14	0.17	0.28	0.18
13	Econ	0.19	0.35	0.24	0.20	0.23	0.25	0.27	0.17	0.30
14	Entrep	0.24	0.30	0.31	0.19	0.19	0.19	0.23	0.19	0.22
15	Ethics	0.20	0.27	0.21	0.23	0.24	0.29	0.17	0.34	0.27
16	H&S	0.17	0.27	0.16	0.19	0.29	0.27	0.23	0.30	0.30
17	HR	0.27	0.24	0.41	0.20	0.22	0.21	0.29	0.20	0.21
18	Innov	0.18	0.42	0.28	0.18	0.27	0.30	0.27	0.22	0.34
19	KM	0.17	0.27	0.34	0.18	0.23	0.22	0.23	0.21	0.24
20	Law	0.13	0.34	0.24	0.11	0.39	0.40	0.31	0.21	0.46
21	Market	0.20	0.27	0.33	0.19	0.23	0.22	0.25	0.19	0.24
22	MotivLead	1.00	0.17	0.25	0.33	0.16	0.15	0.19	0.21	0.16
23	NPV	0.17	1.00	0.23	0.18	0.30	0.32	0.30	0.18	0.39
24	OrgStr	0.25	0.23	1.00	0.23	0.23	0.24	0.30	0.21	0.25
25	Persnlty	0.33	0.18	0.23	1.00	0.10	0.11	0.19	0.18	0.13
26	PM_Monit	0.16	0.30	0.23	0.10	1.00	0.65	0.31	0.19	0.46
27	PM_Plan	0.15	0.32	0.24	0.11	0.65	1.00	0.31	0.19	0.49
28	Procure	0.19	0.30	0.30	0.19	0.31	0.31	1.00	0.17	0.31
29	ProfMemb	0.21	0.18	0.21	0.18	0.19	0.19	0.17	1.00	0.20

30	ProjCost	0.16	0.39	0.25	0.13	0.46	0.49	0.31	0.20	1.00
31	Quality	0.19	0.28	0.33	0.15	0.37	0.35	0.31	0.22	0.33
32	RiskMan	0.17	0.38	0.26	0.14	0.35	0.37	0.33	0.21	0.37
33	Enviro	0.16	0.33	0.24	0.14	0.33	0.37	0.26	0.24	0.39
34	Society	0.21	0.17	0.21	0.22	0.15	0.18	0.18	0.38	0.20
35	Strategy	0.27	0.30	0.35	0.22	0.19	0.21	0.27	0.18	0.25
36	TeamDev	0.40	0.21	0.21	0.29	0.24	0.25	0.22	0.23	0.24

Column		Col. 25 Persnlty	Col. 26 PM_Monit	Col. 27 PM_Plan	Col. 28 Procure	Col. 29 ProfMemb	Col. 30 Proj Cost	Col. 31 Quality	Col. 32 Risk Man	Col. 33 Enviro	Col. 34 Society	Col. 35 Strategy	Col. 36 Team Dev
4	Account	0.17	0.29	0.30	0.24	0.19	0.36	0.27	0.28	0.27	0.17	0.26	0.20
5	Budget	0.17	0.33	0.29	0.33	0.20	0.37	0.32	0.30	0.27	0.15	0.27	0.21
6	BusProces	0.22	0.18	0.17	0.15	0.20	0.25	0.19	0.16	0.16	0.18	0.17	0.22
7	CareerPln	0.23	0.15	0.15	0.15	0.32	0.12	0.16	0.15	0.17	0.28	0.16	0.21
8	PrdCert	0.17	0.18	0.16	0.26	0.21	0.19	0.26	0.17	0.14	0.17	0.23	0.14
9	ChangeMan	0.21	0.25	0.23	0.27	0.14	0.24	0.30	0.28	0.21	0.11	0.32	0.23
10	Communic	0.14	0.47	0.54	0.27	0.25	0.46	0.33	0.33	0.39	0.23	0.20	0.23
11	Contract	0.10	0.46	0.45	0.39	0.19	0.42	0.34	0.37	0.35	0.14	0.19	0.22
12	Cultural	0.25	0.13	0.14	0.17	0.28	0.18	0.19	0.22	0.32	0.35	0.22	0.16
13	Econ	0.20	0.23	0.25	0.27	0.17	0.30	0.21	0.28	0.27	0.19	0.31	0.15
14	Entrep	0.19	0.19	0.19	0.23	0.19	0.22	0.26	0.20	0.23	0.20	0.41	0.20
15	Ethics	0.23	0.24	0.29	0.17	0.34	0.27	0.24	0.30	0.38	0.39	0.22	0.27
16	H&S	0.19	0.29	0.27	0.23	0.30	0.30	0.30	0.32	0.34	0.28	0.16	0.23
17	HR	0.20	0.22	0.21	0.29	0.20	0.21	0.28	0.26	0.19	0.15	0.33	0.26
18	Innov	0.18	0.27	0.30	0.27	0.22	0.34	0.32	0.35	0.33	0.21	0.31	0.21
19	KM	0.18	0.23	0.22	0.23	0.21	0.24	0.27	0.25	0.27	0.22	0.36	0.18
20	Law	0.11	0.39	0.40	0.31	0.21	0.46	0.37	0.43	0.39	0.23	0.25	0.20
21	Market	0.19	0.23	0.22	0.25	0.19	0.24	0.31	0.20	0.21	0.15	0.34	0.20
22	MotivLead	0.33	0.16	0.15	0.19	0.21	0.16	0.19	0.17	0.16	0.21	0.27	0.40
23	NPV	0.18	0.30	0.32	0.30	0.18	0.39	0.28	0.38	0.33	0.17	0.30	0.21
24	OrgStr	0.23	0.23	0.24	0.30	0.21	0.25	0.33	0.26	0.24	0.21	0.35	0.21
25	Persnlty	1.00	0.10	0.11	0.19	0.18	0.13	0.15	0.14	0.14	0.22	0.22	0.29
26	PM_Monit	0.10	1.00	0.65	0.31	0.19	0.46	0.37	0.35	0.33	0.15	0.19	0.24
27	PM_Plan	0.11	0.65	1.00	0.31	0.19	0.49	0.35	0.37	0.37	0.18	0.21	0.25
28	Procure	0.19	0.31	0.31	1.00	0.17	0.31	0.31	0.33	0.26	0.18	0.27	0.22
29	ProfMemb	0.18	0.19	0.19	0.17	1.00	0.20	0.22	0.21	0.24	0.38	0.18	0.23
30	ProjCost	0.13	0.46	0.49	0.31	0.20	1.00	0.33	0.37	0.39	0.20	0.25	0.24
31	Quality	0.15	0.37	0.35	0.31	0.22	0.33	1.00	0.35	0.32	0.18	0.28	0.21
32	RiskMan	0.14	0.35	0.37	0.33	0.21	0.37	0.35	1.00	0.39	0.21	0.26	0.22
33	Enviro	0.14	0.33	0.37	0.26	0.24	0.39	0.32	0.39	1.00	0.29	0.26	0.19
34	Society	0.22	0.15	0.18	0.18	0.38	0.20	0.18	0.21	0.29	1.00	0.20	0.21
35	Strategy	0.22	0.19	0.21	0.27	0.18	0.25	0.28	0.26	0.26	0.20	1.00	0.23
36	TeamDev	0.29	0.24	0.25	0.22	0.23	0.24	0.21	0.22	0.19	0.21	0.23	1.00

Table A2: Correlation matrix for the various topics.

Association rules analysis for 'Communication' as the body

Rule	Body	==>	Head	Support (%)	Confidence (%)	Correlation (%)
57	Communic	==>	PM_Plan	36.57143	74.75292	75.992
58	Communic	==>	ProjCost	30.59341	62.53369	69.50231
62	Communic	==>	PM_Monit	28.83516	58.9398	68.83529
69	Communic	==>	PM_Plan, PM_Monit	27.25275	55.7053	68.17885
59	Communic	==>	Law	27.07692	55.34591	65.98607
65	Communic	==>	Ethic	26.9011	54.98652	61.3529
61	Communic	==>	Contract	26.15385	53.45912	64.65127
66	Communic	==>	PM_Plan, ProjCost	25.97802	53.09973	67.05207
56	Communic	==>	TeamDev	23.38462	47.79874	55.35094
60	Communic	==>	Enviro	22.50549	46.0018	60.85466

68	Communic	==>	PM_Plan, Contract	22.32967	45.64241	61.95804
67	Communic	==>	PM_Plan, Law	22.28571	45.55256	62.61851
64	Communic	==>	H&S	22.06593	45.10332	56.35226
72	Communic	==>	ProjCost, PM_Monit	21.75824	44.47439	62.25632
70	Communic	==>	PM_Plan, Ethic	21.71429	44.38455	61.16888
55	Communic	==>	Work Activity == PlanDesign	21.71429	44.38455	46.77842
73	Communic	==>	PM_Plan, ProjCost, PM_Monit	20.92308	42.7673	61.39917
71	Communic	==>	ProjCost, Law	20.65934	42.22821	60.01703
63	Communic	==>	RiskMan	20.35165	41.59928	56.51643

Table A3: Association rules for 'communication' as the body. These show that many respondents who thought communication (body) was important also thought that various other topics were important. For example Rule 57 is that 37% of respondents said that both communication and Project Planning were important. Furthermore, of those who identified Communication, 75% also identified Project Planning. From this one infers that there is relatively strong association between these two topics.

Association rules for 'communication' as the head.

Rule	Body	==>	Head	Support(%)	Confidence(%)	Correlation(%)
148	PM_Plan, ProjCost, PM_Monit	==>	Communic	20.92308	88.14815	61.39917
136	ProjCost, PM_Monit	==>	Communic	21.75824	87.14789	62.25632
111	PM_Plan, Law	==>	Communic	22.28571	86.0781	62.61851
129	ProjCost, Law	==>	Communic	20.65934	85.29946	60.01703
106	PM_Plan, ProjCost	==>	Communic	25.97802	84.67049	67.05207
127	PM_Plan, Ethic	==>	Communic	21.71429	84.30034	61.16888
120	PM_Plan, Contract	==>	Communic	22.32967	84.10596	61.95804
124	PM_Plan, PM_Monit	==>	Communic	27.25275	83.44549	68.17885
54	Enviro	==>	Communic	22.50549	80.50314	60.85466
85	PM_Monit	==>	Communic	28.83516	80.39216	68.83529
45	Law	==>	Communic	27.07692	78.67178	65.98607
77	Contract	==>	Communic	26.15385	78.1866	64.65127
12	PM_Plan	==>	Communic	36.57143	77.25162	75.992
32	ProjCost	==>	Communic	30.59341	77.2475	69.50231
94	RiskMan	==>	Communic	20.35165	76.78275	56.51643
96	H&S	==>	Communic	22.06593	70.40673	56.35226
102	Ethic	==>	Communic	26.9011	68.45638	61.3529
5	TeamDev	==>	Communic	23.38462	64.09639	55.35094

Table A2: Association rules for 'communication' as the head.

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