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Abstract

In the undergraduate engineering program at Griffith University in Australia, the unit 1006ENG Design and Professional Skills aims to provide an introduction to engineering design and professional practice through a project-based learning (PBL) approach to problem solving. It provides students with an experience of PBL in the first-year of their programme. The unit comprises an underpinning lecture series, design work including group project activities, an individual computer-aided drawing exercise/s and an oral presentation. Griffith University employs a 'Student Experience of Course' (SEC) online survey as part of its student evaluation of teaching, quality improvement and staff performance management processes. As well as numerical response scale items, it includes the following two questions inviting open-ended text responses from students: i) What did you find particularly good about this course? and ii) How could this course be improved? The collection of textual data in in student surveys is commonplace, due to the rich descriptions of respondent experiences they can provide at relatively low cost. However, historically these data have been underutilised because they are time consuming to analyse manually, and there has been a lack of automated tools to exploit such data efficiently. Text analytics approaches offer analysis methods that result in visual representations of comment data that highlight key individual themes in these data and the relationships between those themes. We present a text analytics-based evaluation of the SEC open-ended comments received in the first two years of offer of the PBL unit 1006ENG. We discuss the results obtained in detail. The method developed and documented here is a practical and useful approach to analysing/visualising open-ended comment data that could be applied by others with similar comment data sets.

Keywords: Engineering Education; Project-Based Learning; First-Year Design; Student Evaluation of Teaching; Text Analytics.

1 Introduction

Design is an essential element of engineering education – the rationale being that 'design' is the essential characteristic of engineering practice (Dym, Agogino, Eris, Frey, & Leifer, 2005; Schubert, Jacobitz, & Kim, 2012). Exposure to aspects of design are typically distributed throughout the undergraduate engineering curriculum (Davis, Gentili, Trevisan, & Calkins, 2002). Student design projects have long been used as a key pedagogical element for the development of engineering student design knowledge and skills. Historically, these have taken two complementary forms:

- First-year design courses – often referred to as 'cornerstone' design courses; and
- Final-year design courses – often referred to as 'capstone' design courses.

Cornerstone design courses arose in response to perceptions that first-year engineering curricula, historically loaded with math, physics and other theoretical foundation studies, often left commencing students wondering what engineers actually do. It is suggested that first-year design courses enhance commencing student motivation and retention, and introduce engineering application content and basic design experience early in the curriculum (Dym et al., 2005). There exists a range of pedagogical models, badged with a range of names, for teaching engineering design. However, generically, one of the most common is project-based learning (PBL) (Agouridas, 2007). A wide variety of practices with varying purposes are subsumed under the banner of PBL (Helle, Tynjälä, & Olkinuora, 2006), however in the literature (Frank, Lavy, & Elata, 2003; Helle et al., 2006; Macías-Guarasa, Montero, San-Segundo, Araujo, & Nieto-Taladriz, 2006; Prince & Felder, 2006) there can be found a general consensus that PBL incorporates the following elements:

- solution of a problem or completion of a task requiring students to complete a number of educational activities that drive learning;
- generally, students work in teams to complete a project;
- the project is non-trivial and often multidisciplinary in nature, requiring work over an extended period of time;
- normally, the project involves the development of a concrete artefact – a design, a model, a thesis, a computer simulation, etc.;
- the culmination of the project is often a written report and/or oral presentation describing the project methods and the final product; and
- teaching staff take an advisory rather than authoritarian role.

The Griffith School of Engineering offers four-year Bachelor of Engineering (BEng) and three-year Bachelor of Engineering Technology (BEngTech) degrees at its Nathan and Gold Coast campuses, in Queensland, Australia. The BEng programs are accredited by Engineers Australia, the Australian engineering professional body. Those programs offered on the Gold Coast campus were restructured to facilitate a common first-year. A new first-year unit '1006ENG Design and Professional Skills' was created in the revised structure. The unit aims to provide an introduction to engineering design and professional practice through a project-based approach to problem solving. PBL is used in a number of units in the program, and 1006ENG provides students with an experience of PBL in their first-year. The unit comprises an underpinning lecture series, design work including group project activities, individual Computer Aided Drawing (CAD) exercises and an oral presentation.

Many PBL case studies are documented in the literature, but these case studies are frequently little more than unit descriptions presenting the implementation details of individual courses. More serious evaluation is harder to find (Helle et al., 2006). Detailed evaluations of the initial and subsequent offerings 1006ENG were undertaken, and the full results have been previously published (Hall, Palmer, & Bennett, 2012; Palmer & Hall, 2011). The evaluation was based on a survey of enrolled students that sought responses from students relating to:

- respondent demographic information;
- prior experience with PBL;
- prior perceptions of key pedagogic elements of 1006ENG;
- perceptions of the experience of aspects of 1006ENG; and
- open-ended comments on the 'best aspects' and 'needs improvement' elements of 1006ENG.

In summary, the findings from the evaluations of both offerings were similar, and included: the respondent samples were representative of the whole unit enrolment; the responses were not significantly different between demographic sub-groups; about half of the respondents had previous experience with PBL; respondents generally enjoyed the unit; and, rating responses to the question "Do you enjoy giving oral presentations?" was significantly lower than other responses. The open-ended comments provided important additional insights into students' perceptions of the unit.

Griffith University employs a 'Student Experience of Course' (SEC) online survey as part of its student evaluation of teaching, quality improvement and staff performance management processes. The SEC survey is opened for students to voluntarily complete towards the end of the teaching period, but prior to the examination period, so SEC data are unlikely to overly influenced by students' perceptions of how they performed on the exam and/or the unit overall. The SEC survey instrument contains six scale items, framed as questions, to which students can indicate their level of agreement with on a five-point response scale. Additionally, the SEC survey contains the following two open-ended response items to which students can provide a free text response:

- SEC7 - What did you find particularly good about this course? and
- SEC8 - How could this course be improved?

The SEC scale items (SEC1 to SEC6) are generic for use in all units of study at Griffith University, so are generally not similar to those used in the separate evaluations of 1006ENG noted above. However, the two open-ended text response SEC items are sufficiently similar to those employed in the previous evaluations of 1006ENG to provide a complementary set of text-based evaluation data.

The collection of textual data in surveys is commonplace, due to the rich descriptions of respondent experiences they can provide at relatively low cost. However, historically these data have been underutilised because they are time consuming to analyse manually, and there has been a lack of automated tools to exploit such data efficiently (Bolden & Moscarola, 2000; Jackson & Trochim, 2002). It is possible to manually tabulate the frequency of common themes observed in text data (Hall et al., 2012; Palmer & Hall, 2011). A simple form of computer-based analysis is visualisation using word clouds - a visual representation of the ranked frequency of occurrence of words in a text source (Hall & Palmer, 2015; Miley & Read, 2012). More sophisticated computer-based analysis and visualisation of textual data goes by various names, including lexical analysis, concept mapping, text mining, and text analytics. We will use the latter term as the general name for describing, "… a set of linguistic, statistical, and machine learning techniques that model and structure the information content of textual sources for business intelligence, exploratory data analysis, research, or investigation." (Hu & Liu, 2012, p. 388). A typical visualisation output from text analytics software is a two-dimensional (2D) chart that identifies key words or themes in the source text, indicates the relative frequency or importance of those words/themes, and represents in 2D some aspect of the relationships between the words/themes. There are many published examples of text analytics applied to open-ended text data, including survey comments, but case studies using student evaluation of teaching data are much less common. This paper presents a text analytics-based evaluation of the SEC open-ended comments received in the first two years of offer of the unit 1006ENG. We address the method developed and the results obtained in detail.

2 Methodology

Approval was sought from the Griffith University Human Research Ethics Committee to use the data presented on the SEC reports from the initial and subsequent offering of the unit 1006ENG, and approval was granted. The text analytics software package KH Coder (Higuchi, 2014; Ishii, Suzuki, Fujii, & Fujiyoshi, 2013; Minami & Ohura, 2013) was used to analyse the text content of the open-ended comments from the SEC surveys. KH Coder was selected as it is free and provides a range of analysis and visualisation options. KH Coder supports the use of a dictionary of 'stop words', that is, words to be ignored in any analysis of the text (Hu & Liu, 2012). Common English words and parts of speech, such as 'I', 'a', 'am', 'be', 'my', 'the', etc., add little to the analysis, and their relatively high frequency often masks the words/terms that are actually of significance (Bolden & Moscarola, 2000). A stop word dictionary was developed based on the example English stop word dictionary supplied with KH Coder, after inspection to remove any words likely to be relevant in the context here, such as 'computer'. A second issue that can mask the significance of words/terms in text analytics is the presence of inflected and/or derived forms of words, for example, a root word such as 'write' may also be present in the source text as 'writing', 'wrote', 'written', etc. KH Coder implements 'stemming' to consolidate inflected and derived words into their root form. Stemming via lemmatisation (Bolden & Moscarola, 2000) based on English parts of speech (nouns, proper nouns, adjectives, verbs, etc.) was used. In text analytics a 'unit of analysis' is required, that is, the smallest elemental grouping of text upon which the analysis will be based. KH Coder supports sentences and paragraphs as units of analysis. In the data, each student comment was represented as a paragraph, so paragraphs were chosen as the unit of analysis. KH Coder supports a range of text data analysis and visualisation methods – the two employed here were the co-occurrence network (CON) (Namey, Guest, Thairu, & Johnson, 2007) and hierarchical cluster analysis (HCA) (Bridges Jr, 1966).

Co-occurrence refers to the presence of two (or more) terms in the same text unit of analysis – here we are interested if the same term groups frequently co-occur in student comments. KH Coder uses the Jaccard distance (Hu & Liu, 2012) as a measure of co-occurrence for term pairs. Based on specifying the minimum frequency of occurrence of a term for inclusion in the CON analysis and visualisation, terms appear as nodes in a network plot based on the Fruchterman and Reingold layout algorithm (Fruchterman & Reingold, 1991). Frequently co-occurring terms in the visualisation are connected by lines/edges. It is possible to configure the plot to indicate the relative frequency of terms by the relative size of their node, and to indicate the relative frequency of co-occurrence of terms by the relative thickness of the edge connecting their nodes. HCA produces a unique set of nested clusters by agglomeration - sequentially pairing terms, and then clusters of terms, using a clustering method applied to a distance measure for those terms. KH Coder supports a number

of distance measures and clustering methods – here we use the Jaccard distance (Hu & Liu, 2012) and the Ward clustering method (Blashfield, 1976). Based on specifying the minimum frequency of occurrence of a term for inclusion in the HCA analysis, and the number of clusters desired, the resultant dendrogram locates closest together those terms within clusters, and then those clusters of terms, that have the lowest distance measure (dissimilarity coefficient). The visualisations resulting from the CON and HCS analyses were examined to find evidence of key themes in the student open-ended comments provided in the SEC evaluation survey.

3 Results

For the initial offering of 1006ENG, the SEC report contained 83 SEC7 'good about this course' comments and 85 SEC8 'course be improved' comments, from a unit enrolment of 237. In the subsequent offering, the SEC report contained 44 SEC7 'good' comments and 40 SEC8 'be improved' comments, from a unit enrolment of 260. Based on the separate formal evaluation of the initial offering of 1006ENG (Palmer & Hall, 2011), some targeted refinements were made to the unit learning design for the subsequent offering (Hall et al., 2012), however these were essentially points of finesse rather than significant structural changes to the content, teaching methods or assessment. Particularly for the subsequent offering of 1006ENG, the number of comments was modest. Pooling of student evaluation data is a suggested approach to create a more significant data set (Aungles & Karmel, 2000). Based on the fact that the unit learning design was largely identical between the two offerings, the comment sets were pooled to obtain 127 'good' comments and 125 'be improved' comments for analysis. Figure 1 presents the CON visualisation for the 'good' comments generated using KH Coder.

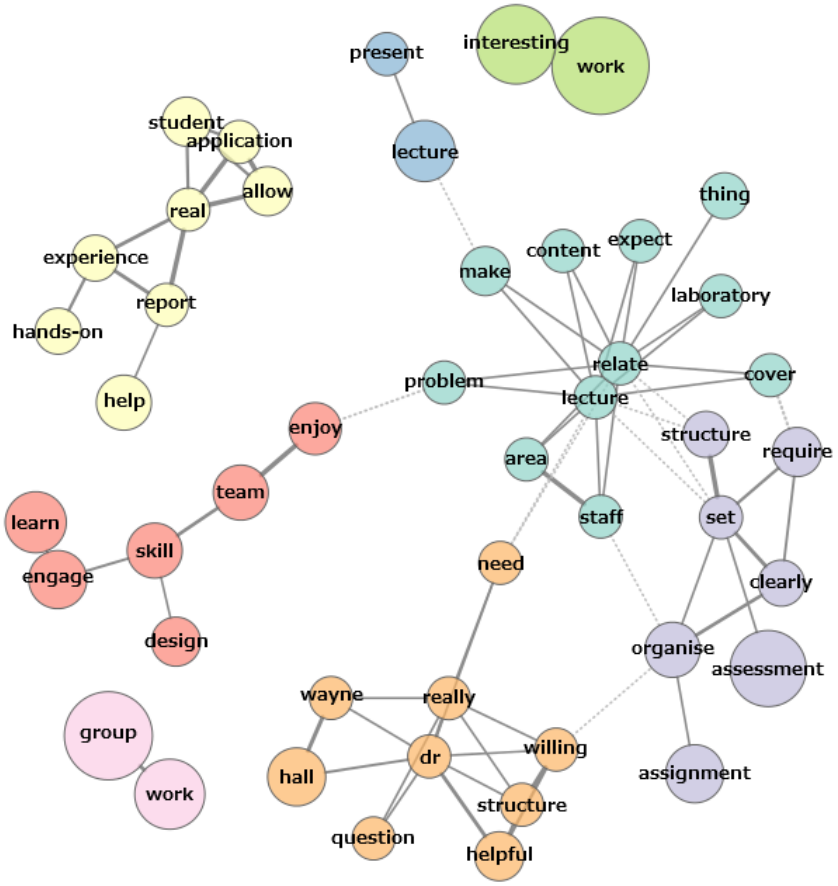

Figure 1. Co-occurrence network for 'What did you find particularly good about this course?' student comments.

Figure 2 presents the CON visualisation for the 'be improved' comments generated using KH Coder.

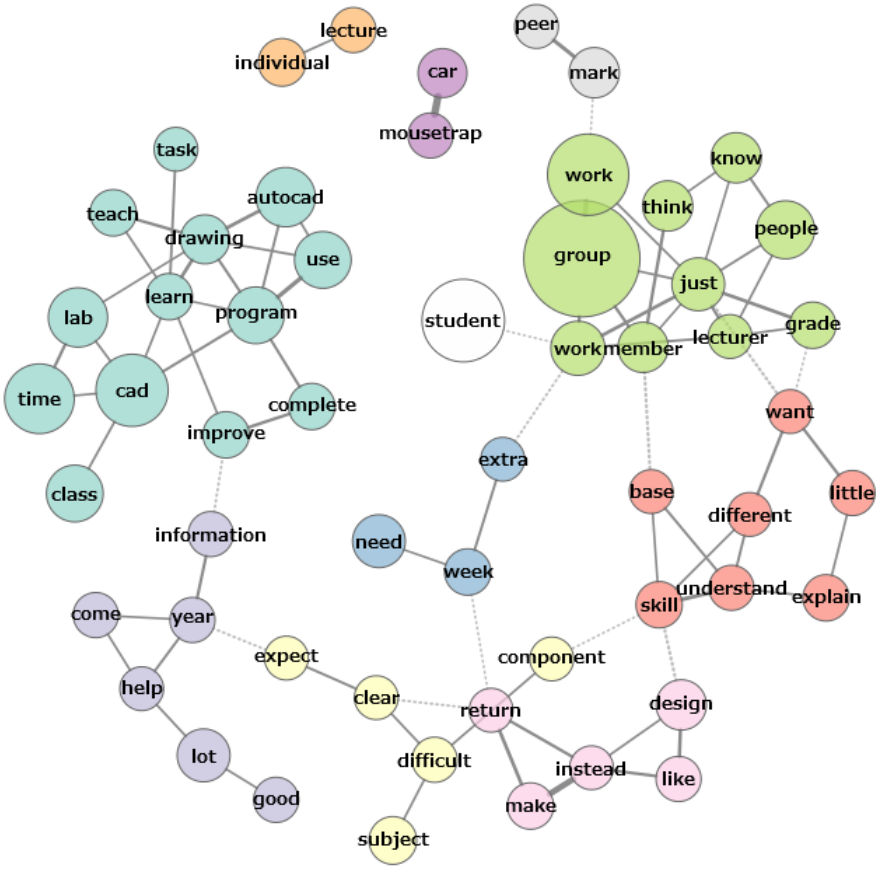

Figure 2. Co-occurrence network for 'How could this course be improved?' student comments.

Figure 3 presents the HCA dendrogram visualisations for the 'good' (left) and 'be improved' (right) comments, based on 7 clusters, with the cluster number indicated. The horizontal bars in Figure 3 are a relative frequency histogram for the terms in the dendrograms. The scales at the bottom of Figure 3 give the values of the dissimilarity coefficient for each clustering pair at that point in the agglomeration process.

4 Discussion

Figure 1 and Figure 3 were examined to identify 'good' themes that were prominent, especially similar themes that were common to both visualisations. Table 1 summarises the findings. Figure 2 and Figure 3 were similarly examined to identify 'be improved' themes, and Table 2 summarises the findings. The visualisations of the 'good' comments revealed themes representing a number of the benefits of PBL claimed in the literature, including experience of group/team work, experience of design processes, and experience of aspects of engineering practice. Additionally, students perceived a number of desirable characteristics of good teaching, including a helpful lecturer and clear assessment requirements. Finally, students reported that the PBL format was interesting and engaging. The CON and HCA visualisations for the 'good' comments showed a high level of consistency in the themes apparent. A key purpose of student evaluation of teaching is to identify areas of the unit learning design and/or delivery that could be revised to improve the students' experience – to this end the 'be improved' visualisations were examined. Figure 2 (CON) showed two large clusters related to group work (including peer marking) and CAD (including learning to use AutoCAD and CAD class time). Additional themes apparent include the mousetrap car project, the time demands of the project work, the need for explanation of design skills, and assessment feedback (an almost universal theme in student evaluation of teaching). Again, the CON and HCA visualisations for the 'be improved' comments showed a high level of consistency in the themes apparent.

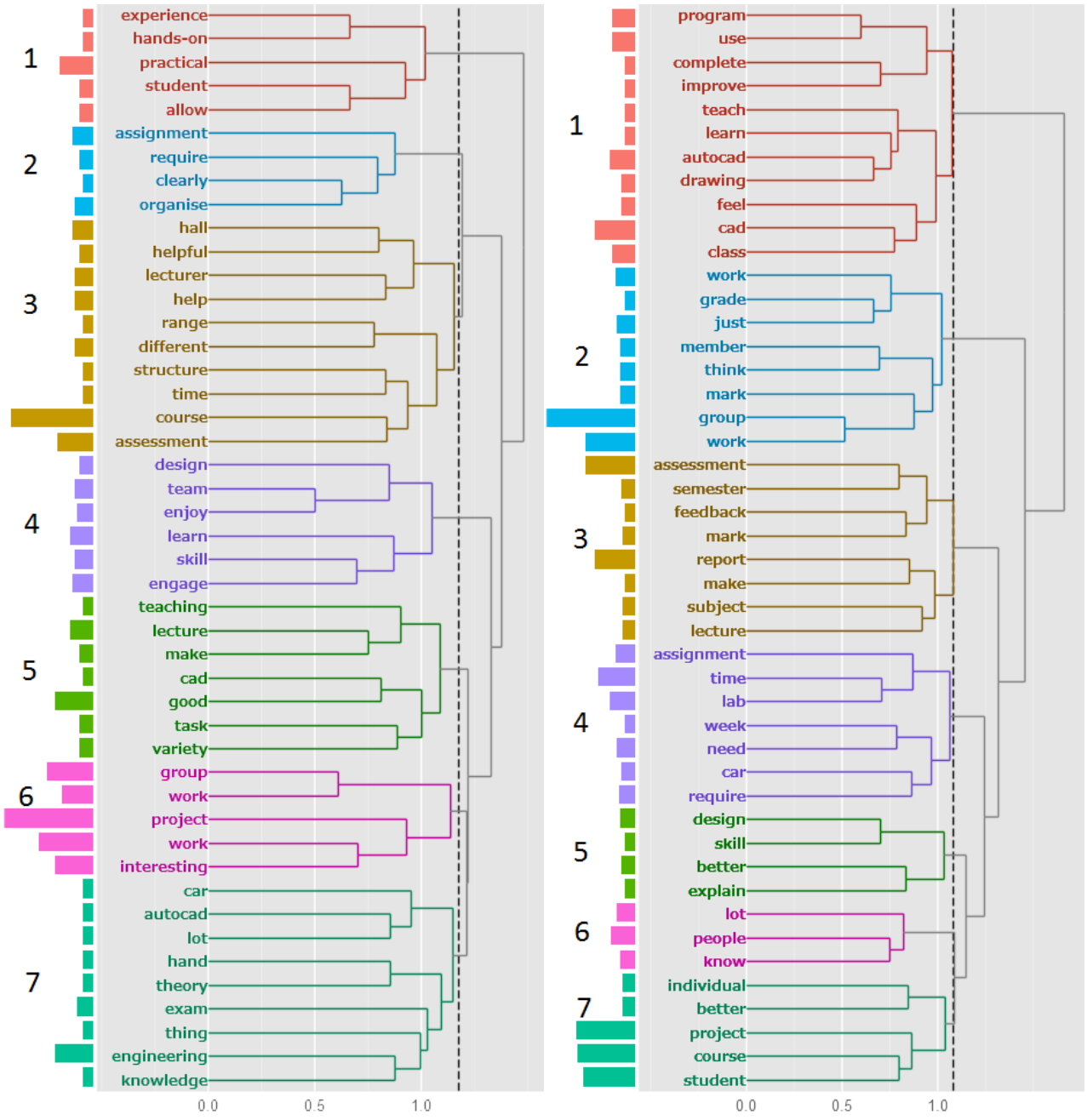

Figure 3. Hierarchical cluster analysis dendrograms for 'What did you find particularly good about this course?' (left) and 'How could this course be improved?' (right) student comments.

KH Coder provides a key-word-in-context (KWIC) concordance feature that can identify the locations in the source comments of phrases that contain one or more specified keywords within a specified distance of each other (Bolden & Moscarola, 2000). Based on identifying pairs/groups of terms appearing in the CON and HCA visualisations that are of interest to investigate further, the KWIC concordance feature allows these term groupings to be located in their original comment context for consideration. The previous evaluation of 1006ENG contained two open-ended text response items asking students about the best aspects of 1006ENG, and those aspects of 1006ENG that most need improvement. While these questions were not identical to the SEC7 and SEC8 items, they were very similar, and provided a point of triangulation for the results obtained here. As previously reported (Hall et al., 2012), based on manual analysis of the student comments from the initial and subsequent offerings of 1006ENG, the principal 'best aspects' identified by students were: group work; the hands-on/practical nature; enjoyable project work; the assessment (specifically that there was no

Table 1. Prominent themes in the SEC7 'What did you find particularly good about this course?' student comments.

Theme	Terms from Figure 1	Terms from Figure 3 (left) [cluster number]
Interesting work	interesting-work	interesting-project-work [6]
Group work	group-work	group-work [6]
Unit assessment	set-assessment-structure	assessment-course-structure [3]
Practical/real experience	student-real-experience-hands-on	student-practical-hands-on-experience [1]
Engaging learning	learn-engage	learn-engage [4]
Helpful lecturer	dr-wayne-hall-helpful	lecturer-hall-helpful [3]
Team design enjoyable	enjoy-team-design-skill	enjoy-team-design [4]
Assignment requirements clear	assignment-requirements-clearly-organised	assignment-requirements-clearly-organised [2]
Exposure to engineering		engineering-knowledge [7]
Variety of tasks		cad-good-task-variety [5]

exam); the CAD component; and the helpful staff. The principal 'needs improvement' suggestions from students were: more instruction on CAD; better explanation of expectations; more even group participation; a better spread in assignment due dates; the heavy workload of the projects; and more feedback on work. The key themes from the open-ended student comments in both evaluations were largely the same, providing a measure of cross-validation between the two sets.

Table 2. Prominent themes in the SEC8 'How could this course be improved?' student comments.

Theme	Terms from Figure 2	Terms from Figure 3 (right) [cluster number]
Group work	group-work group-member-work	group-work [2] know-people [6]
CAD classes	time-cad-lab	cad-class [1]
Use of AutoCAD	use-autocad-program teach-learn-drawing	autocad-drawing [1]
Mousetrap car project	mousetrap-car	need-week-lab-time-car [4]
Peer assessment	peer-mark lecturer-just-grade	group-work-mark [2] better-individual [7]
Time demands	need-extra-week	assignment-time-lab [4]
Explanation of basic design skills	explain-understand-base-skill difficult-subject-clear	better-explain-design-skill [5]
Assessment feedback		semester-assessment-feedback-mark [3]

5 Conclusion

A method for analysing student evaluation of teaching comment data with the free KH Coder text analytics software package to produce relevant and informative visualisations was developed. Co-occurrence network and hierarchical cluster analysis visualisations were found to provide a useful overall representation of the key words/themes in SEC comment data, and they exhibited good consistency between the visualisation forms. Key 'good' themes that students identified about 1006ENG included: group/team work; experience of design; experience of engineering practice; helpful lecturer; clear requirements; and PBL was interesting and engaging. Key 'be improved' themes included: group work (including peer marking); learning to use AutoCAD; CAD class time; the mousetrap car project; the time demands of project work; explanation of design skills; and assessment feedback. These findings were largely in agreement with the outcomes of a separate evaluation of 1006ENG. The text analytics method developed for analysing SEC open-ended comment data using the KH Coder software package produced useful comment text visualisations that, in turn, provided a valuable perspective on these comment data in a straightforward and timely manner. The method developed and documented

here is a practical and useful approach to analysing/visualising open-ended student evaluation comment data that could be applied by others with similar comment data sets.

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