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Research Article

Assessing the impact of natural language processing-driven clustering on engineering students' growth in mentoring programs

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ABSTRACT

Although they help to build engineers, the mentoring programs hardly are reviewed number-wisdom, based on what learners say. Through that gap comes this work - based upon the voices of 3,362 pupils stretched over a ten year span of disciplines, year by year of study. Only by filtering comments with the help of such tools as sentiment decoding and group-finding algorithms, patterns could be observed. There were six distinct filaments that emerged: project assistance and grants advice, on-campus assistance and career guidance, personal development and assistance with research issues. Where opinions were floating freely, numbers took form. The score of 0.7985 on the silhouette score was a confirmation of the optimal number of clusters, which was also supported by the measures used, such as WCSS, Calinski-Harabasz, and Davies-Bouldin. Positive sentiment constituted almost 84.6 percent of the answers - confirming that mentorship helps in the development of learners. This is a good look at numbers to get a clear understanding of how students are going through these programs, which points to practical steps schools can implement. Rather than basing the analysis on intuition, the use of detailed analysis introduces new approaches to evaluate mentoring arrangements, closing gaps left unanswered in previous studies and informing future changes with evidence.

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INTRODUCTION

Mentoring is exceptional in most learning facilities and in particular in engineering studies where demands are fast accumulated. In the process of creating future engineers, the path is more than coursework - coaching takes place in the face of actual challenges, including personal challenges. Since these degree paths are pressuring in terms of time, energy, and concentration, the presence of someone who has been through it all assists the learners to remain grounded. Lectures are not what lead to success; it is lifelong progress that is intertwined with the human relationship. The workload feels heavy at times, layered with expectations few anticipate before starting. Mentoring gives tailored assistance so learners can manage tough situations while gaining stronger

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grades, greater self-assurance, yet better preparation for jobs. Research shows mentoring addresses the educational and subjective needs of engineering students to assist with their success as well as provide them an avenue to stay in the field. An integral component of acquiring engineering ability comes down to a continual advising relationship. With the courses considered some of the most difficult in educational institutions, students in many cases bear a major workload of course work, challenging research tasks and group tasks. With good mentoring comes crucial advising, support which has a significant impact on student success in college also at subsequent stages of development.

The need for Mentoring for Engineering Students

Tackling challenging coursework can take its toll on engineering students. When mentoring occurs, the eyes are opened - to how people execute tasks, manage their time, day in and day out. Rather than attempting to get through challenges on their own, the supported learners in this study benefit from strategies, support. Research indicates it helps improve marks, while reducing the risk of early withdrawal [1]. Typically, engineering pupils seek advice when looking for internships and jobs. As experienced travellers, mentors know about changing job demands. Through interactions, students better understand making industry connections. Befriending advice, options for development are less daunting. The dialogues increase the chance of achieving goals [2]. Employing high pressure, engineering study can at times make students feel isolated or stressed [3]. But support from mentors helps - to reduce nerves, boost self-confidence, as speaking helps to change the perspective. Although learning is intimate, it's enhanced by human interactions. As such, self-confidence is not just based on acquired knowledge but on having a champion [4]. Having someone listen makes the struggle worthwhile, able to be sustained. That quiet encouragement? It's there when you need it. Often, engineering education mentors do much more than advise and cheer up their students [5]. Typically, they are experienced teachers, professional engineers, or senior peers who have compete information to provide guidance through the roadblocks of education, profession and personal challenges. Their understanding of understanding of fundamental engineering principles and potential careers also allows specific advising within practical contexts [6].

Mentor Responsibilities

Guidance and support

Diving in right away, mentors help students to set specific learning and career goals. Advice often relates to choosing certain courses, assignments or career options. One contribution they make is to offer words of wisdom during times of great stress. Dealing with significant deadlines, support can help. But tackling challenging designs is less daunting when you know you don't have to go it alone. Help is sometimes subtle - more listening than talking Bad times go better with a buddy.

Role modeling

Engineers gain ethics, problem solving skills, from mentors. Through role modeling, students explore assumptions of product designs. During project challenges, learner engineers' mentors solve problems step by step. Such observations transform apprentices' responses to uncertainty in a project. Witnessing innovative solutions boosts apprentices' faith in systematic thinking.

Feedback and evaluation

Mentor feedback can guide students to make improvements to their work, such as a paper, project or presentation. Opportunities for learning rely on understanding, and so advice can be provided on what is going well as well as what needs to change. Examples in practice could be critiques and discussions of engineering summaries or feedback following fieldwork experiences.

Networking and opportunities

Mentored students are introduced to professionals often during events such as conferences. Practical experience is the part exhilarating hands-on work comes from contacts. Agname drop might help access lab experience few can get.. Training places sometimes are filled by a timely self-assertion.

A starting point may be through looking at text feedback from 3,362 students in different stages and groups of engineering. Instead of simply tallies, analyses using sentiment detection reveal insights about learning support - particularly working on skill for their work, training for jobs and help on campus - that draw deductions from experiences. As these comments reveal points of help, these findings support Vygotsky's notion that learning progresses when people can receive assistance just in time. What's interesting is how student feedback reflects the journey from 'being' to independence - through mentoring.

This approach using clustering methods, reflects on continuing changes and patterns in students' opinions about mentoring. Student expectations vary with time in clustered responses. Results relate to Bandura - learning influenced by contact with others and mentors. Groupings create patterns - semester-to-semester differences.

Understanding improves and engagement increases, focus is sharpened. They learn: academically and for careers due to guidance.

This research differs as it influences more effective mentoring strategies to match evolving engineering learners as their knowledge and confidence grow, leading to better learning and greater outcomes. Mentoring has long been a highlight in the growth of future engineers at school. Studies show performance and learning are linked to such programs, as careers get a break start and students gain confidence. Reflections on previous research show how some types of mentoring relationships work. Patterns of types of support emerge (some by students, some by faculty) and these affect outcomes. Identity and race can change who and how much.

Retention (staying enrolled) and degree completion tend to improve with advising programs. The following synthesises insights about these relationships from a series of studies? Our learning is often observational Bandura put it like this - we learn by watching. A teacher's example is more important than instruction. Advice is more effective when it's based on experience. Attitude changes are subtle, through habituation. A good role model provides a good example. Mentors' actions are more important than words. Learning comes by observing, as well as doing. Good habits are learnt through contact with talent. Behaviours are spread by example. Students learn a lot from closely watching mentors, so they develop working habits, and how to solve problems and communicate them [7]. Patterns of feedback explored here reveal practices that enhance the impact of mentorship in practical learning - to mimic good role models. Input from an expert enables places for learning beyond independent work alone - a key element of Vygotsky's development zones theory. By gradual support and guidance, mentors allow students to stretch to more complex tasks that they couldn't do alone. Thoughts like age-old career planning or project steering demonstrate how we can use small cues to gradually build trust and confidence in students' growing independence [8]. While bringing together such models, the research reveals mentoring aids student learning via social (observational) learning and support [9], facilitating course and career building practices [10]. The Peugeot Center Model was investigated by Dodson and colleagues in 2022 and involves integrating mentoring within relevant engineering challenges, improving students' applied skills, cross-cultural skills and engagement. Engaging in industry-relevant scenarios, the model places theory and practice in context, fostering critical and design thinking.

Continuing support led to greater engagement, and higher grades. Rather than individual contact, ongoing relationships made the difference. Agholor, with de Nalda and Bárcena three years ago launched the idea of shaping the engineers of the future with structured mentoring in higher education settings. By creating opportunities for mentoring, skill development thrives; both technical and interpersonal skill building occur. Where human identity meets mentoring programs, there are differences; ethnicity and gender take on new meanings in mentoring. In 2017 Aikens and her peers examined the effect of mentoring on undergraduate research outcomes - racial minorities had access to less mentoring. Given this imbalance, culturally-sensitive mentoring techniques would seem to be needed for equitable experiences [11]. Jumping forward to 2021, Tuladhar's team explored what shapes the paths of African American students in engineering, spotlighting informal networks and visible role models within mentorship. These aspects, it turned out, played a key part in helping underrepresented learners feel they truly belonged while also doing well academically [12]. Then there is Dennehy and Dasgupta's work from 2017: their focus fell on how having women peers as mentors influenced whether female students stayed in engineering programs. Early peer mentoring may enhance how women experience academia, boosting their chances of staying in engineering programs [13]. Research into such support systems shows consistent links to better student results. A 2010 analysis by Budny, Paul, and Newborg found mentored first-year engineers performed stronger academically, sticking with their studies more often [14]. Work led by Still maker and colleagues in 2020 looked at whether instructor gender affects guidance offered to women pursuing engineering. Female faculty members often help female students thrive - especially within engineering, where men are more numerous [15]. Not long ago, Gehr and colleagues showed how guidance from professors shapes graduate learning in engineering. At one public university, close advising ties boosted both scholarly output and fulfilment among learners [16]. Supportive connections between teachers and pupils appear linked to better persistence in tough degree paths. Mendez's team pointed out that meaningful bonds involving Black instructors and their mentees matter deeply. One reason these connections matter is how they turn teacher insights into better outcomes for learners, especially those from marginalized backgrounds. During the pandemic, Saw and colleagues in 2023 looked at gaps in guidance and emotional well-being among American undergraduates. What stood out was that strong mentorship softened the blow of isolation and stress on grades and mood, showing its value when conditions get tough [17]. In another case, Rayford's team two years later found younger engineering majors gained both socially and scholastically through mentors close in age. Evidence points to advising bonds lifting involvement, persistence, completion - especially where support runs thin [18].

This work looks into how NLP-driven grouping methods affect mentorship within engineering learning, bringing practical uses for teachers, school leaders, corporate collaborators, and counsellors. Results reveal ways to boost academic performance, keep students enrolled longer, and prepare them better for jobs - all while aiding emotional well-being and encouraging varied participation. Such discoveries may shape teaching plans, rules, and course design over time. While centered on engineering classrooms, the approaches apply just as well elsewhere - across fields or regions - for those aiming to lift education standards using strong mentoring frameworks.

MATERIALS AND METHODS

This paper follows a systematic approach to the research topic of the role of mentoring in engineering students, based on the written feedback obtained during several academic semesters. According to Figure 1, the process starts with the group assignment of mentees, and periodical guidance meetings. Then, the feedback is gathered with the help of feedback forms that will be completed by the participants. These are then subjected to the pattern detection process through machine learning. The overall effectiveness is assessed as the last step, with regard to the tendency of clustered responses.

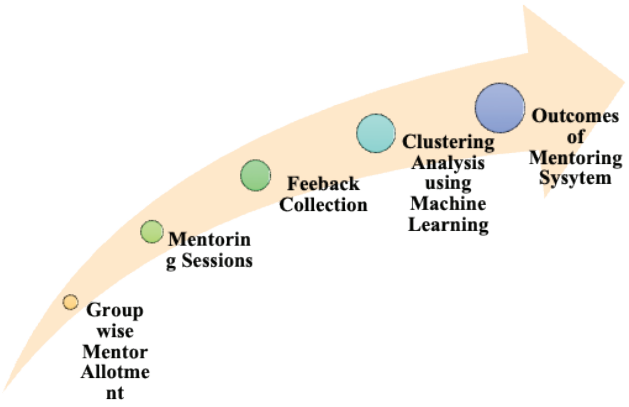

Figure 1. Methodology.

Group-Wise Mentor Allotment

Purpose: To make sure that, mechanical engineering students in India will be provided by personalized guidance through the mentors during their academic course, their academic performance, their readiness to enter the career, and their overall development will be improved. By using systematic scheduling whereby certain time is allocated to mentoring, faculty can balance between mentoring and their academic life since the time allocated to mentoring is at a single time and as such, it does not interfere with teaching, research and administrative activities. Peer learning and collaboration can be achieved by group mentoring sessions that are able to make the most of time. Co-mentoring or teaching assistant models of collaborative mentoring assist in distributing the workload and offering different perspectives. Also, incorporation of mentoring with academic work, including coursework or research projects, will make sure that mentoring does not interfere with other duties, but instead, it supplements them. The support of the institutions such as the acknowledgment of mentoring in workload calculations and the provision of professional development opportunities is also important. The strategies will help the faculty to strike a balance between mentoring and professional obligations.

Mentor Selection

Objective: Look for mentors that can teach mechanical engineering students and industry pros are hired. Selected candidates must be able to articulate well. Experience with industry is critical. Encouraging communication is favored. Students are reviewed before admitted. Matching is done to student needs. Long-term involvement is encouraged. Good mentoring is key to success. Roles are defined in each partnership.

Look for those with deep knowledge of the discipline - well-experienced academics, company engineers with experience, or highly productive senior undergraduates. Examples are faculty members heavily engaged in mechanical design courses, practitioners who work in the areas of automotive or flight technologies, or undergraduates who perform well in fundamental courses. One practice is to look through past experience in research projects, followed by looking through record of mentoring given in past projects. Look past titles when selecting to mentor; participation more important than position. Typically, those already supportive of helping others are selected.

Look at credentials first - mentors face scrutiny via experience, training, background screening, references, and depth of understanding of a subject, communication, ability to provide feedback, time availability, cultural compatibility, and various development activities

A mentor should have a good grasp of mechanical engineering so, a university lecturer who is an expert in heat and liquid flow - good. Or perhaps someone out of the car industry who has tackled problems in industry for years.

For mentors, specific knowledge of mechanical engineering is most important. Mentors should understand key concepts and how to apply them. A robotics expert could be suitable. Or a lecturer in structural analysis might be also suitable. Out of classroom experience enhances their worth.

Being available is a feature of mentoring. It is crucial the mentor's calendar is open for discussion. An interest in helping forms the basis of the mentor-mentee relationship. Involvement rings in showing leadership, listening well, responding well. Time reflects a commitment to learn. Encouragement takes little actions, done consistently. Advice is best delivered as a mental organically given service, rather than receiving a service by obligation.

Following identification of potential mentors, the next step is selection processes. Those selected then prepare by attending workshops. This involves focusing not only on theory but practical methods of mentoring. Awareness of what learners are challenged by is a focal point of the program. Techniques for providing feedback are role-played and practiced so they're instinctive when delivered to learners. Creations of positive environments are practiced during the program. Training continues only until participants are confident in certain aspects.

Industry Professional Allotment Process

1. Determining Mentor-Student Ratio:

Typically, an industry specialist caters to four or five students. This is a good balance - attention can be focused, but also doesn't overwhelm the guide.

The number of industry professionals required will be determined by student numbers. If the number of students is 100, we need approximately 20 - 25 industry experts? On the other hand, much fewer are needed for smaller class sizes and more are needed for larger class sizes.

2. Finding Professionals to Work With:

Alumni can help in locating professionals to mentor others. Recent graduates in employment, such as aerospace, automotive or production get approached through university-based social networks. This contact is made using platforms like LinkedIn, as well as graduate societies.

Collaborating with firms that are engaged with the mechanical engineering program - as employers for student placements, visiting lecturers or engaged in joint research projects - helps identify potential mentors. These may stem from on-going development projects in which mentoring roles arise. Companies already involved with the department generally provide academically minded people. In projects identified, needs lead to appropriate personnel. Links forged in work-based learning stages lead to mentoring relationships. Engagement in practical work creates avenues to mentoring relationships. Collaboration towards common aims assists identifying mentors.

Collaboration with organizations such as ASME leads to those working in mechanical engineering. These connections develop organically and mostly through working towards a common goal. Engagement generally occurs at conferences and meetings. Networks facilitate access typically denied estranged. Project creation can be casual, stemming from interest. Trust is developed gradually over time. Knowledge is shared profusely in projects. Multi-year involvement is preferred to one-offs.

3. Getting Industry Insurance Professionals to Get Involved:

There is an interest for pros to participate as it enhances skills like team work and communicating. Participation expands networks - between organizations, as well as professionals. Visibility is gained, too, with insights into trends in research. Experience is also developed, along the way, changing the way people make contributions.

Thanks come in the form of public thanks, including on the internet. Being involved could result in a later collaboration on studies. Participants may get written acknowledgement.

Because of busy schedules, experts can decide their frequency of participation - every few weeks or monthly - known as juries, online. Scheduling is flexible per individual, as needs and schedules vary.

Session Length and Format

Each meeting typically lasts half an hour to 40 minutes so there's time for discussion, and so the students aren't overloaded.

Prior to each meeting, a theme is assigned. This includes topics to be discussed. This ensures that things will run smoothly. Topics listed in advance at a meeting provide a flow of discussion. Understanding is achieved through knowing what will be discussed. Attention is maintained with an outline. Planning promotes better meetings

- Academic Advising (e.g., course and exam preparation)
- Employment Advice (e.g., job-related skills, interviews)
- Personal Development (e.g., technical, soft and management skills)
- Personal Well-being (e.g. stress management, workload)

Session Planning and Flexibility

These are meetings prearranged early in the semester, via the university's systems or e-mail notices. These are scheduled rather than coinciding, throughout the term.

If changes occur, the mentor and student can rearrange the meeting to proceed with the plan - this enables the project to proceed regardless of changes to study plans or other commitments.

First Year Student Timeline Example

August: Orientation and welcoming to the mentoring program

Meetings are bi-weekly between September and December to help with settling into the year, as well as develop skills

Half-year meetings are held in January to inform goals. Targets emerge around this period, shaping future. Mid-year reviews impact improvement, shaping next steps. Plans unfold for the next semester; plans are also impacted. Reflection times mark month's path forward

February - May: Ongoing twice-weekly sessions, with new focus on electives and revision

Evaluation and improvement

After each session, we collect feedback - this helps to evaluate how effective a session was, and inform what's coming up (adjusting dates and content). Participants' feedback accompanies adjustments to improve sessions, without aiming to stick to pre-planned structures.

Documentation

Digital recording of adjustments, such as collaborative documents or guidance systems can speed up tracking the learner's progress and minimizing paper. These systems helps updates to go live across devices, eliminating re-entry. Progress reports are easier to access as they are stored electronically. Techniques like this shift paper to simplicity. Data can more easily get from teacher to students.

The focus in on the next step. Thorough records draw attention to positive outcomes rather than a heap of details. This allows mentors to focus on supporting people, rather than paperwork.

Meeting minutes

There are meeting summaries created after each meeting; brief reports to keep you up to date. Objectives, agenda items and action items are accompanied by details. When developing a group project idea, between a mentor and student for instance, the summary will contain the objectives and anticipated outcomes. Everyone's roles are distributed accordingly, with dates if necessary. Progress reports might be added later.

Session outcomes

Progress notes taken frequent meetings assist with monitoring progress and efficacy. Reflections from discussions inform future decision making about inadequate support in the future.

Example:

A few mechanical engineering second years have advisors with expertise in their targeted fields. These guiders and learners meet bi-weekly. In one such meeting, the learner mentions being unsure about what electives might best lead to a career in robotics. Advice is given; not just on what subjects to study but also extra-curricular pursuits. Gaining experience from projects might be recommended. Knowledge emerges in a two-way dialogue - decisions emerge without formulas. Knowledge also evolves, as a result of authentic talk and practice. Objectives are discussed - how to raise grades in certain subjects are gradually developed. There's a record - simple, straightforward: the learner's intention is on paper. Additional tutoring could occur; commitment to a team building robots might form.

Feedback collection

Students' feedback drives good mentoring outcomes for engineering students. It focuses on students' program experiences. We take their opinions into account when evaluating support.

1) Objective

The goal of collecting feedback is to assess the mentoring program. The first assessments are made through student feedback about halfway down the term. A crucial element is to identify potential improvements. Further reviews follow at the end of the year. These provide a better view of impacts on learning. Information at various times supports learning checks as well as judgements.

2) Survey Design

The feedback surveys ask about the different stages of mentoring, but also mentors' communication style. Areas examined include the helpfulness of advice shared. Surveys indicate how satisfied mentees are through fixed-answer questions that blend elements of a scale and comment boxes. Instead of monomeric measures, a mixture of numbers and comment is used. Each approach has slight variations for each program stage. What's impressive is the non-overlapping collection of information about timings, clarity and supports

For example, numbers are used: for instance, a rating of one to five: one being strongly disagree, five being strongly agree, on a trait. The responses measure attitudes towards specific issues, becoming increasingly positive. Each numerical position represents an opinion, well organized but simple. Ratings concern aspects being studied, with a clear pattern of numbers. This converts opinions into this information, so they can be compared

- Mentor's accessibility and inter-personal skills.
- The mentor's advising ability.
- The mentors' relevance and helpfulness.
- Overall experience with the mentor.

3) Feedback Timing and Multiple Feedback Points

As the year unfolds, opportunities for feedback are garnered from a variety of phases. This ensures that feedback is delivered with some time to process, overridden by feedback over time. Stages provide differing perspectives. Responses help us understand how things are moving on even months later. Thinking small, often, avoids impact

Immediately, we use brief check-in responses to each mentoring meeting - to check for problem areas. Meanwhile, students can anonymously communicate in a secure online environment.

In feedback, mid-term provides an opportunity to identify issues. If sent mid-way through semester 1, students can work on any adjustment before term-end. This assessment occurs as part of the mentorship process, and encourages ongoing development. Any problems noted can be addressed later. It's reasonable to do it right now - it will be useful in the near future. Students may indicate issues with scheduling time for meetings with the mentor and the mentoring relationship may change accordingly. Occasionally there are timing problems, and the strategy is changed a little to optimize the process. Schedule availability frequently has an impact on the guidance cycle, and requires adjustments from participants. As access to them is sometimes problematic, an occasional shift may be needed. The wave changes a bit when the days in between them are missing from the calendar.

Deviations may arise as a student might identify difficulties in scheduling time to meet their mentor, which will affect the mentoring. Occasionally there are timing problems, and the strategy is changed a little to optimize the process. Schedule availability frequently has an impact on the guidance cycle, and requires adjustments from participants. As access to them is sometimes problematic, an occasional shift may be needed. The wave changes a bit when the days in between them are missing from the calendar.

4) Data Analysis and Interpretation

By analyzing the survey's numbers, we identify common themes in student satisfaction. Ratings are analyzed using a statistical technique to find the success of mentoring. Scores are analyzed by grouping by frequency of response. Common ideas are identified by calculation. Patterns ensure when scores are ranked. Patterns stand out and can be finds representative. Any duplication is indicative of outcomes holding across students.

The system begins with unfiltered comments and NLP to analyses emotional attributes in responses. Rather than have a single person review the work, multiple reviewers can review the texts independently. To ascertain agreement, their decisions are compared for their agreement rate. This minimizes bias while helping to achieve an unbiased conclusion.

Each step in seeking feedback is ethical, including disclosing details about the feedback session before people participate; letting people choose freely to participate and ensuring people can leave if they choose. Trust and safety ensue when learners' protected honest opinions are valued in an environment of their choosing.

Clustering Analysis Using Machine Learning

Objective:

The objective of clustering analysis using machine learning is to uncover underlying patterns and themes in student feedback. By grouping similar feedback responses, the analysis helps to identify common experiences, sentiments, and areas that require attention in the mentoring process.

Feature extraction

- TF-IDF Vectorization: This technique converts the preprocessed text data into numerical features that can be used by machine learning algorithms [19].
- Term Frequency (TF): Measures how frequently a word appears in a document.
- Inverse Document Frequency (IDF): Measures how unique a word is across all documents [20]
- TF-IDF Score: Combines TF and IDF to give a score that highlights important words that are frequent in a particular document but rare across others.
- Example: The phrase "mentor support helpful" in one feedback might have a high TF-IDF score for "mentor" and "helpful," indicating their importance.

Clustering

- Analysis Algorithm: Many clustering algorithms are considered, frequently the simplest and most effective (K-means) algorithm.
- K-means Clustering: This algorithm divides the data into K clusters, such that each feedback is allocated to a cluster it is closest to in terms of features [21].
- Alternative Algorithms: Other algorithms such as Hierarchical Clustering or DBSCAN might be used, depending on the data [22].
- Finding the Right Number of Clusters:
- Silhouette Score: Calculates how closely related an object is to the cluster it is a part of relative to other clusters. The higher the score the clearer the clusters [23].
- Elbow Method: A line graph is plotted based on the within-cluster sum of squares for various numbers of clusters, and the "elbow" where the decrease begins to diminish is determined, optimal number of clusters.
- For instance, following K-means clustering you might find that 5 is the optimal number of clusters to separate feedback responses[24].

Cluster Analysis

- New Themes: Each cluster is analysed to find the most common words and phrases that constitute each cluster, identifying new themes in the feedback
- Example: A cluster might be based around "academic support" and phrases such as "goal," "study plan" and "course selection" may be common.
- Sentiment Analysis: The feedback in each cluster can be analysed to determine the overall sentiment (positive, negative, neutral) [25].
- Example: "Mentor availability" might show a combination of positive and negative sentiments, depending on whether students could reach their mentors or not.
- Identify Student Experiences: Patterns of student experiences are identified, providing opportunities to improve a program.
- Example: A cluster based on "communication skills" could reveal students value communicative transparency, but think mentors could be faster in responding.

Evaluation of the Mentor

1. Beginning with gather information from the learner, reviews attempt to gauge mentor effectiveness in their support of the learner. Next, observations of mentoring practice help to identify skills performing. Occasionally this includes a mentors' reflections. Overall, using a combination of these methods highlights mentor performance
2. Students rate their mentor immediately after mentoring talks. But they are asked specific questions - about presentation, support, and helpfulness. But answers demonstrate if mentors really disappoint or not. But, it offers a view of how mentoring advice matches the real-life needs. While short, reviews act on lack of connection, effectiveness.
3. The assessment starts with meeting frequency, followed by punctuality. Mentors also must be available in between meetings. Discipline is demonstrated with these actions, and commitment over time. Most important is 'being there' - over and over again without pressure.
4. The benefits of mentorship are measured in students' improved academic scores, skills and judgement skills. Improvements in these areas can be a measure of mentorship. The result is this cycle - help results in progress. Over the long term, learning styles indicate greater learning. Success is subtle, it's in the results.
5. Yet another lens is to have fellow colleagues or supervisors observe mentoring sessions. At times, program managers gather feedback on what mentors are doing. Programs with this type of oversight bring consistency to training. Loops with senior staff can identify issues. Another source of feedback can be from formal checkpoints. Areas needing attention are often pinpointed through these assessments. Voice from several sources promotes equitable judgements of impact.
6. As review may identify gaps, mentors could also attend follow-up training to strengthen their mentoring skills - ensuring sustained development. What's important is ability to adjust follow-up support.

RESULTS AND DISCUSSION

When it comes to numbers of clusters, six is the most prominent given its silhouette value of 0.7985 - the highest observed. This is close to 'one', signaling compact clusters and large gaps between them. Rather than blurring together or breaking apart, the data fall nicely into these six parts. The closer the value is to the top of the -1 to 1 range, the more

certain we can be the structure is real. Segments of six seem to be consistent with naturally occurring dissimilarities in responses. High silhouette values demonstrate close bunching and good separation; so items within one group are similar, and distinct from items in other groups. With six divisions, we can explore what these groups are defined by; what are the top themes and concerns associated with the groups? Such findings suggest improvements to better align strategies for mentoring with what students live. The future lies in revisiting the prominent terms in each cluster and summarizing the insights gained, then making changes based on the data.

WCSS (Within-Cluster Sum of Squares)

With increasing cluster count, WCSS drops steadily - a predictable pattern. When plotted using the elbow technique, a slowing decline should become visible at some point. Yet here, the drop keeps going without clear levelling off, making that approach less useful. Instead, six stands out as the most suitable number, supported by evidence in Figure 2.

Silhouette Score

One way to judge cluster quality is by checking how tightly grouped each point sits within its assigned set. Points standing apart from neighbouring groups tend to yield stronger scores. With a value reaching 0.077932, six clusters pull ahead in performance. This peak appears when exactly half a dozen groupings are used. Seen clearly in Figure 3, this number marks the top result across tested options.

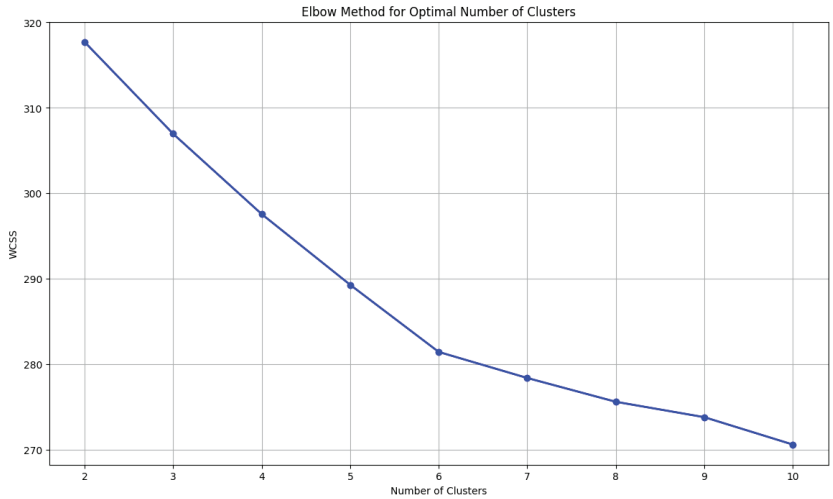

Figure 2. Optimum clusters by elbow method.

Figure 3. Cluster wise Silhouette Score for K Means Clustering.

Davies-Bouldin Index

Starting at 3.397363, the smallest Davies-Bouldin score appears when there are six groups. This index compares each cluster to its closest counterpart, averaging how much they resemble one another. Lower numbers here point to stronger separation between sets. Because the minimum occurs at six clusters, that count fits best under this method. See Figure 4 for the trend across different counts.

Calinski-Harabasz Index

Looking at cluster quality, the Calinski-Harabasz Index compares spread between groups against spread inside them. A greater number suggests stronger distinction. Peaking at 0.992897 when six segments form, it signals a clearer divide than other counts - this peak appears clearly in Figure 5.

Looking at how responses grouped together helps uncover what students really talk about when they mention mentorship. Each group reveals something distinct, shaped by its most common terms:

Cluster 1: Professional Development

Keywords: internship, guidance, helped, practical, company, mentoring, advice, industry, career, find

In the case of this group, there is a focus on job-related work life, job-based mentorship, and growth. The most critical concepts are that learners should find value in the advice that relates them to real work when undertaking placements or roles associated with particular areas. The use of words like company, career and industry is frequent and preparation to working environments is of importance in this case. Coaching assistance also evidently assists to

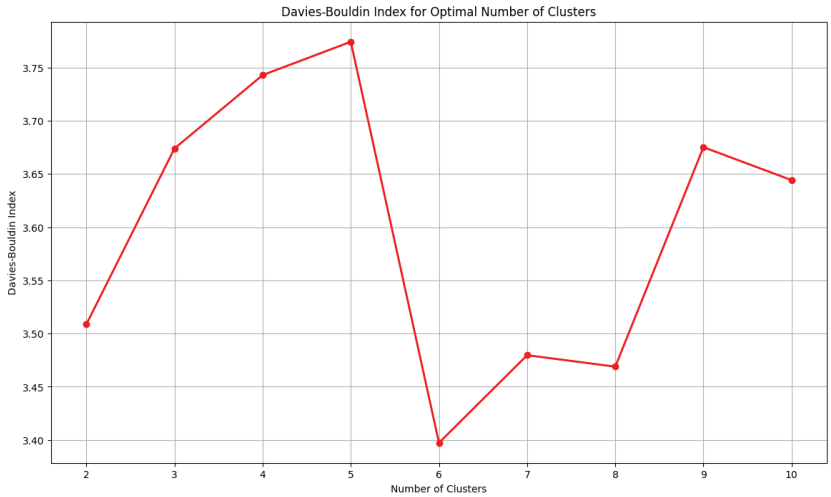

Figure 4. Cluster wise Davies-Bouldin Index.

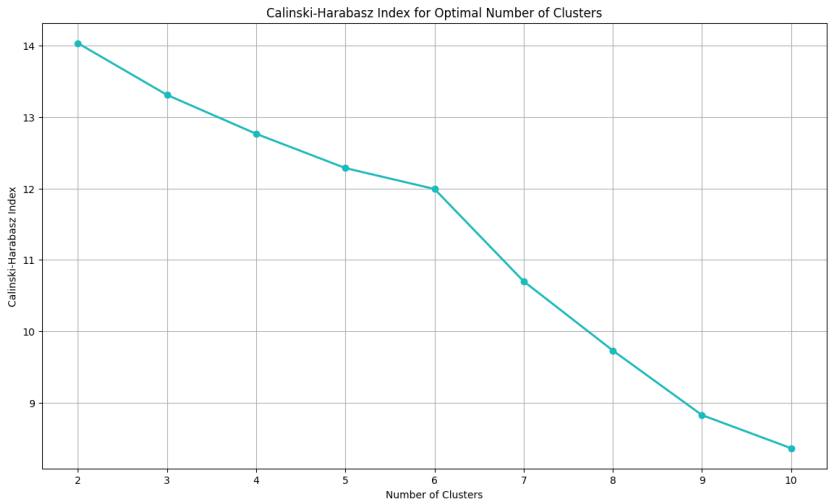

Figure 5. Cluster wise Calinski-Harabasz Index.

develop future decisions. Figure 6 shows a visual representation of these patterns with popular terms included in Cluster 1.

Figure 6. Word Cloud Cluster 1.

Cluster 2: Campus and Community Support

Keywords: cultural, support, campus, feel, mentoring, helped, made, community, activity, event

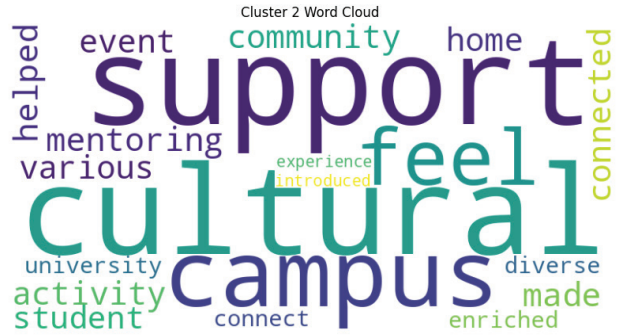

Figure 7. Word Cloud for Cluster 2.

Figures 7 shows a word cloud for Cluster 2

For Cluster 2 mentoring is indeed important to the students on campus. With words such as cultural, community and event used most often, it seems clear the relationships of mentoring help to shape social relations amongst students. Such exchange is open to further engagement than just from a consideration of grades. When there's support, it seems that the students are drawn more into participation. Mentoring streams, for its part, is a subtle element in pervading the ordinary college life. The Word Cloud of Cluster 1 (Figure 7) gives more information.

Cluster 3: Project and Feedback Focus

Keywords: project, provided, mentoring, feedback, session, mentor, continuous, helped, valuable, improved

Figure 8. Word Cloud for Cluster 3.

Looking at Cluster 3, mentoring is one of the important issues regarding project work and making progress. The pattern of keywords in the data results in feedback and frequent workshops. The high number of words such as project, feedback, better suggests learners will benefit from targeted and repetitive instructions. The words are spread as a visual depiction (known as word cloud) of this group across the board in Figure 8.

Cluster 4: Research and Resource Support

Keywords: research, mentoring, provided, helping, helped, develop, needed, resource, methodology, crucial

Figure 9. Word Cloud for Cluster 4.

Cluster 4 is focused on the mentoring in terms of research in academia and research skills support. Words research, methodology and resource are quite common - these refer to the mentor's being engaged in the student's research project. Mentor advice matters - guidance has an impact on the study design and work with data of students. This is shown by evidence when we look at word patterns expressed in replies. We can see a visualisation in Figure 9 and this shows some overlap in words for Cluster 4.

Cluster 5: Scholarship and Application Guidance

Keywords: scholarship, application, advice, clear, successful, helped, mentoring, detailed, led, process

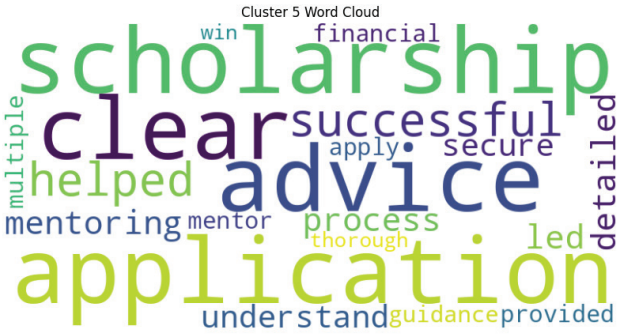

Figure 10. Word Cloud for Cluster 5.

Figure 11. Word Cloud for Cluster 6.

In this cluster, the emphasis is on an approach based on scholarship assistance and follow up with the processes. These terms - scholarship, apply (how to) or advice - are used to highlight how students can benefit from support in applying for scholarships. Most prominent is support where mentors explain and tell learners the specific facts and details. The Word Cloud representation (see Figure 10) of Cluster 5 is shown here.

Cluster 6: Placement and Job Preparation

Keywords: placement, job, interview, provided, mentoring, mentor, session, tip, confidence, resume

Looking at Cluster 6 - it is about finding a job and managing interviews. Care is linked to stronger levels of confidence and better pieces of job applications - words like employment, interview, resume and confidence. Dialogues seem to imply a focus on ways of world-preparedness rather than advising. In this case, the preparation to work will be a dominant motive as it establishes the modes of introducing students to work. We can see the influence of mentors in the way the students will put their CVs to the employer. For example, in Figure 11 the Word Cloud associated with Cluster 6 is shown.

Sentiment Analysis

Most student feedback comes across as clearly approving, based on an analysis of responses from 3,362 individuals. Positive remarks take up 84.56%, standing out when set beside the 8.77% labeled neutral and just 8.67% marked negative. Seen together, reactions form a pattern favoring satisfaction with how mentoring unfolds. Scattered throughout, quiet reservations remain visible but do not shift the general trend. What emerges most distinctly is a tilt toward affirmation rather than doubt. Visualization of this emotional breakdown appears later as Figure 12.

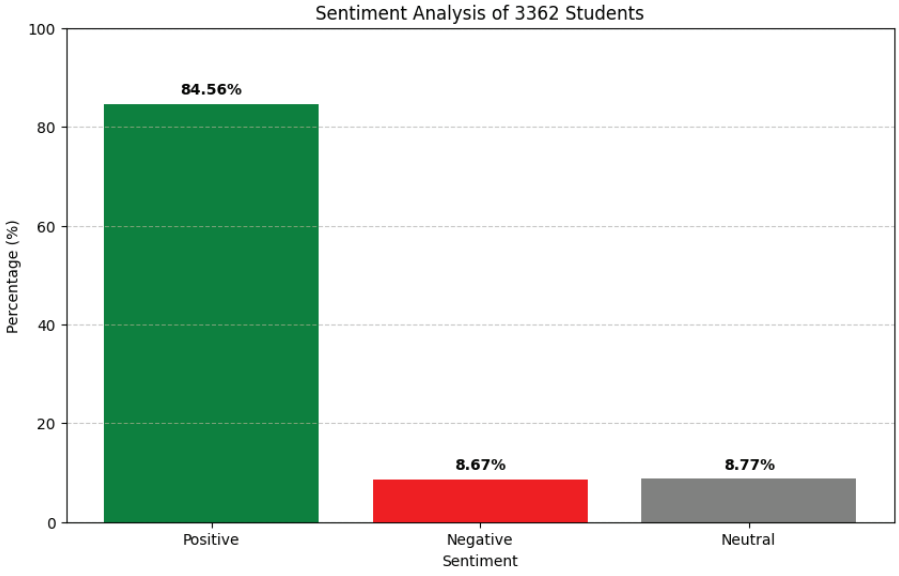

Figure 12. Sentiment Analysis.

Word Network

Figure 13, 14, 15, 16, 17 and 18 shows the word network for cluster 1, 2, 3, 4, 5 and 6

Cluster 1: Internship and Mentoring

Key Words:

o internship, helped, mentoring, guidance, advice, practical, company, find, career, industry

The cluster focuses on the practical aspects of internships and mentoring. Internship and mentoring are central nodes, with frequent connections to words like helped and guidance.

Cluster 2: Campus Culture and Support

Key Words:

Cultural, mentoring, support, campus, helped, feel, made, activity, event, community

Cluster 3: Project and Feedback

Key Words:

project, mentor, mentoring, provided, helped, session, feedback, valuable, improved, continuous

Cluster 4: Research and Resources

Key Words: Research, mentoring, helped, provided, develop, helping, needed, resource, methodology, crucial

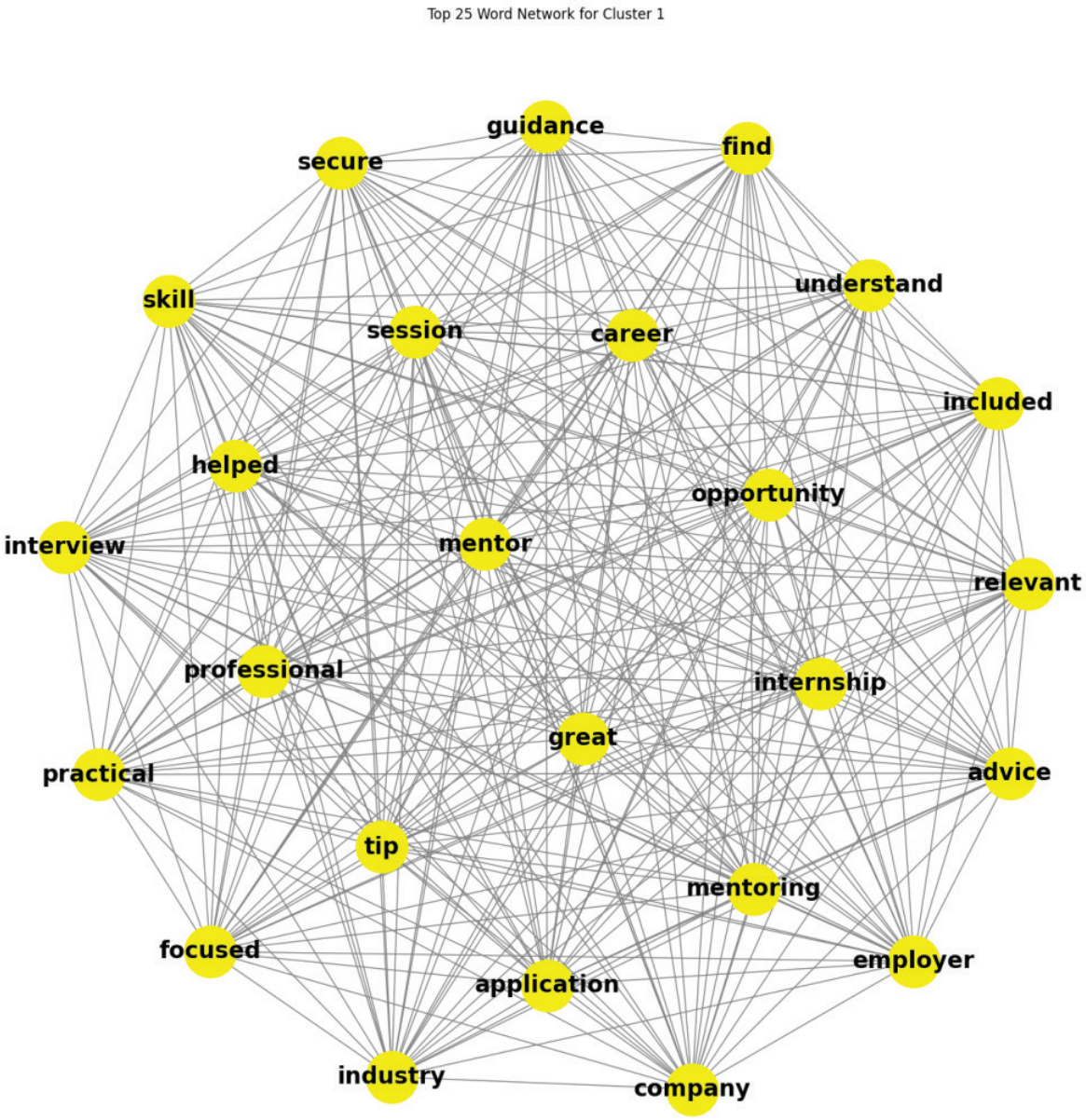

Figure 13. Word network for top 25 words of cluster 1.

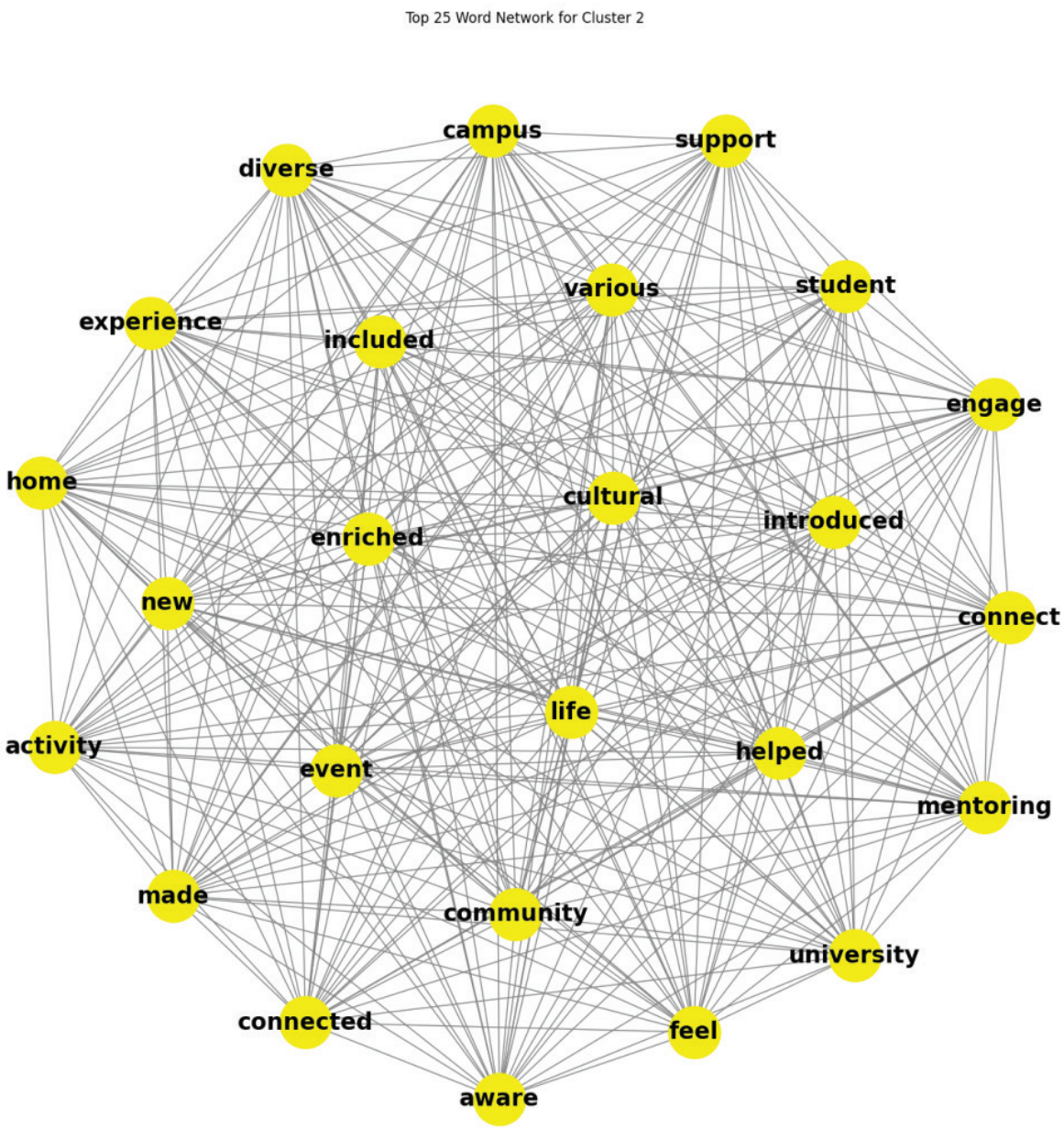

Figure 14. Word network for top 25 words of cluster 2.

Cluster 5: Scholarships and Applications

Key Words: Scholarship, mentoring, application, helped, advice, led, successful, clear, process, detailed

Cluster 6: Placement and Career Preparation

Key Words: Placement, mentor, mentoring, provided, job, interview, session, tip, confidence, resume

Hierarchical Clustering Analysis

And a closer examination of the feedback data via hierarchical clustering reveals six distinct clusters. The dendrogram, in Figure 19, illustrates how each response relates to others based on the similarity. At the point the connected lines cross the horizontal line - at a similarity value of 3 - that is where the clusters split. This divides the branches into six branches. Each grouping is distinct - based on different patterns. These divisions suggests six different themes in the feedback. Opinions and experience fall along these topics; not arbitrarily but in these forms. Rather than being amorphous, responses are drawn around concepts. Clusters form in nature. Six themes emerge from respondents' responses.

To begin with all the data points are individually grouped. Then similar groups merge, based on proximity (in straight-line distance). What you see at the top of the

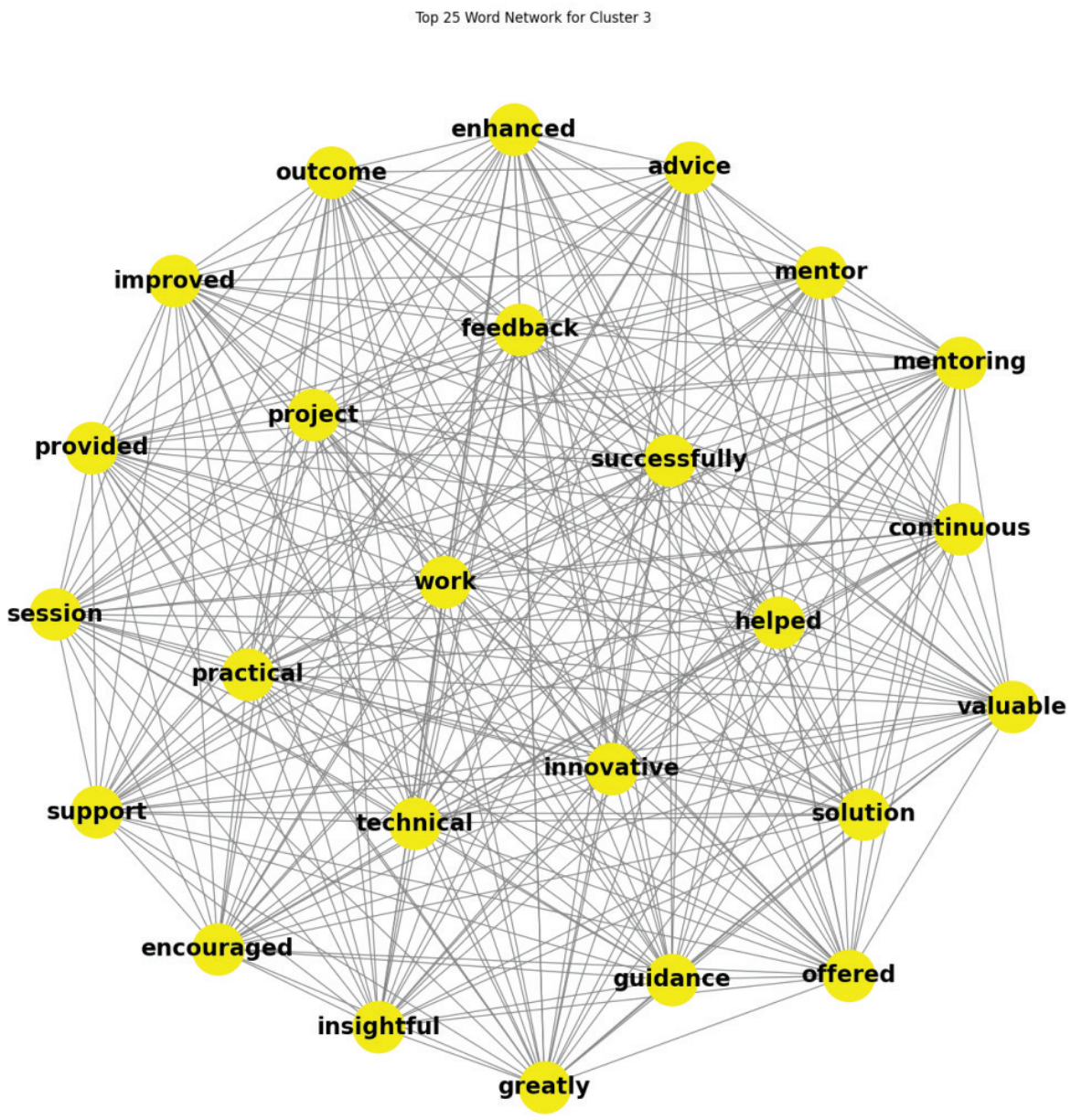

Figure 15. Word network for top 25 words of cluster 3.

branch diagram indicates how far apart the groups were to start with. When the distances between groups are larger than a certain threshold, they no longer join - the line here indicates where divisions are resolved into groups. But the silhouette score was 0.741 - less than K-means' 0.7985. With further investigation, feedback patterns were less consistent for members of different groups.

Table 1 shows the Optimum mentoring clusters. Table 2 shows the mentoring sessions and number of students benefited throughout the 4 years of engineering.

This approach works well when finding oddly shaped groups. Still, too many dots ended up labeled as outliers. Because of that, pieces scattered instead of forming whole units - silhouette stood at 0.689. Themes within each group felt looser than those from K-means splits.

Through 1756 internships, students gain exposure to linking academic work with the workplace. Their mentors support them when selecting placements, rehearsing their interview skills or getting used to the workplace. It provides access to build confidence and skills valued by employers. Practical assignments during these times make them ready for their future jobs. Knowledge is gained progressively in various business settings.

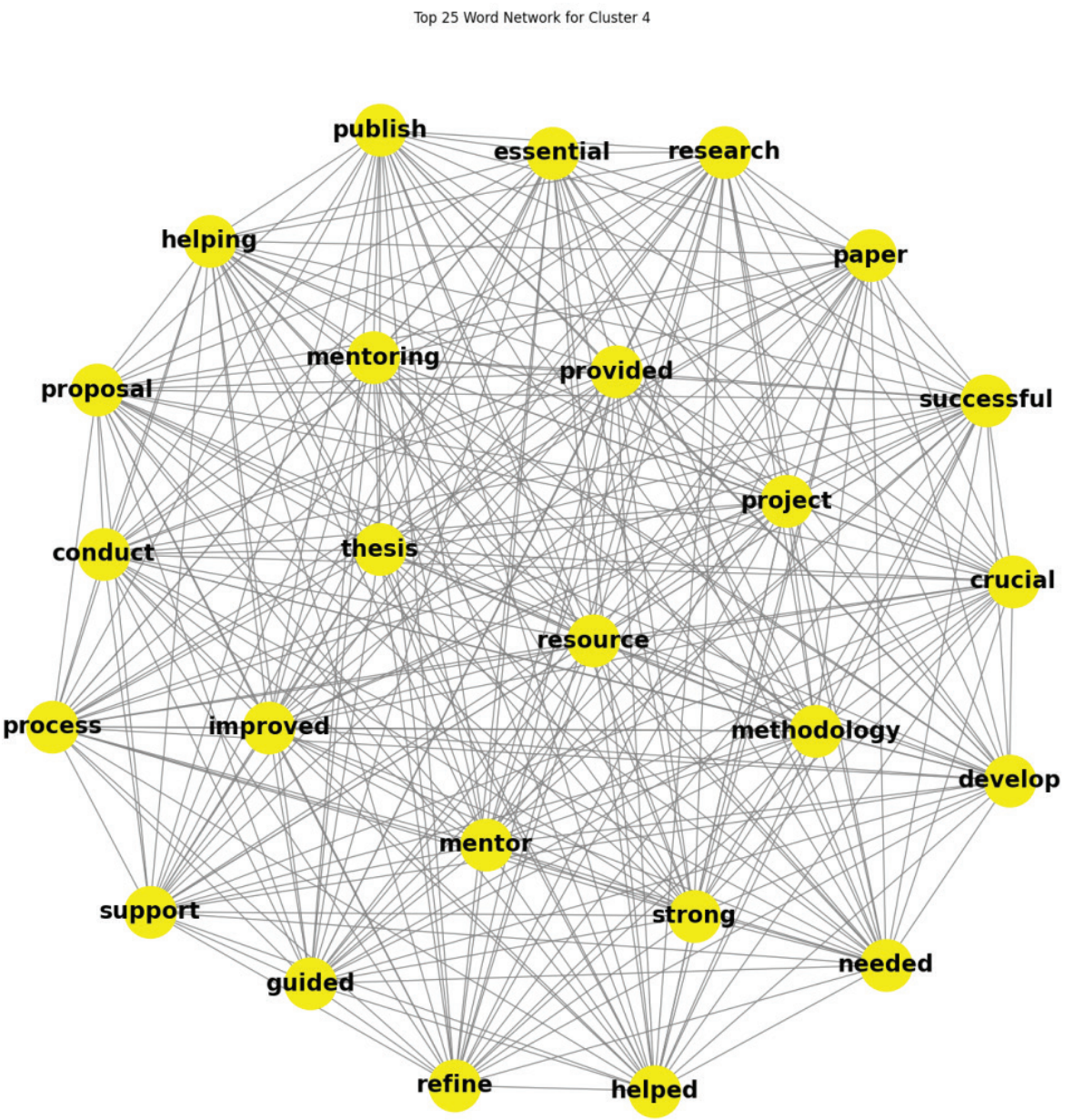

Figure 16. Word network for top 25 words of cluster 4.

Given 1127 students' placements, entry into employment role is a significant transition. Mentors help students to apply for jobs, and so influence how candidates present their capabilities. Some help with CVs; others, interview questions - all guided uniquely. With practice comes better performance. It is success that is low key - placement rates remain consistent. Counselling is adapted to the individual not standardized. Students' progress into work in their own time. Encouragement from input helps make working transitions smooth. Practice makes perfect, advice is advice. When a large number of students are placed, mentors are hard at work.

A smaller group, 563 learners have Higher Education Counseling. These get individuals into postgraduate training, grants and academics. Support is through mentors who advise on appropriate courses, support applications and keep time tables. This doesn't happen as frequently as other support. But such personal support is critical as learners advance to new learning settings.

A quarter of all the mentored learners - 259 - received scholarship support. Given funding relieves financial stress, this lets them focus even more on academics. The mentoring supports people to find suitable awards, develops applications and explains complicated processes. Awards'

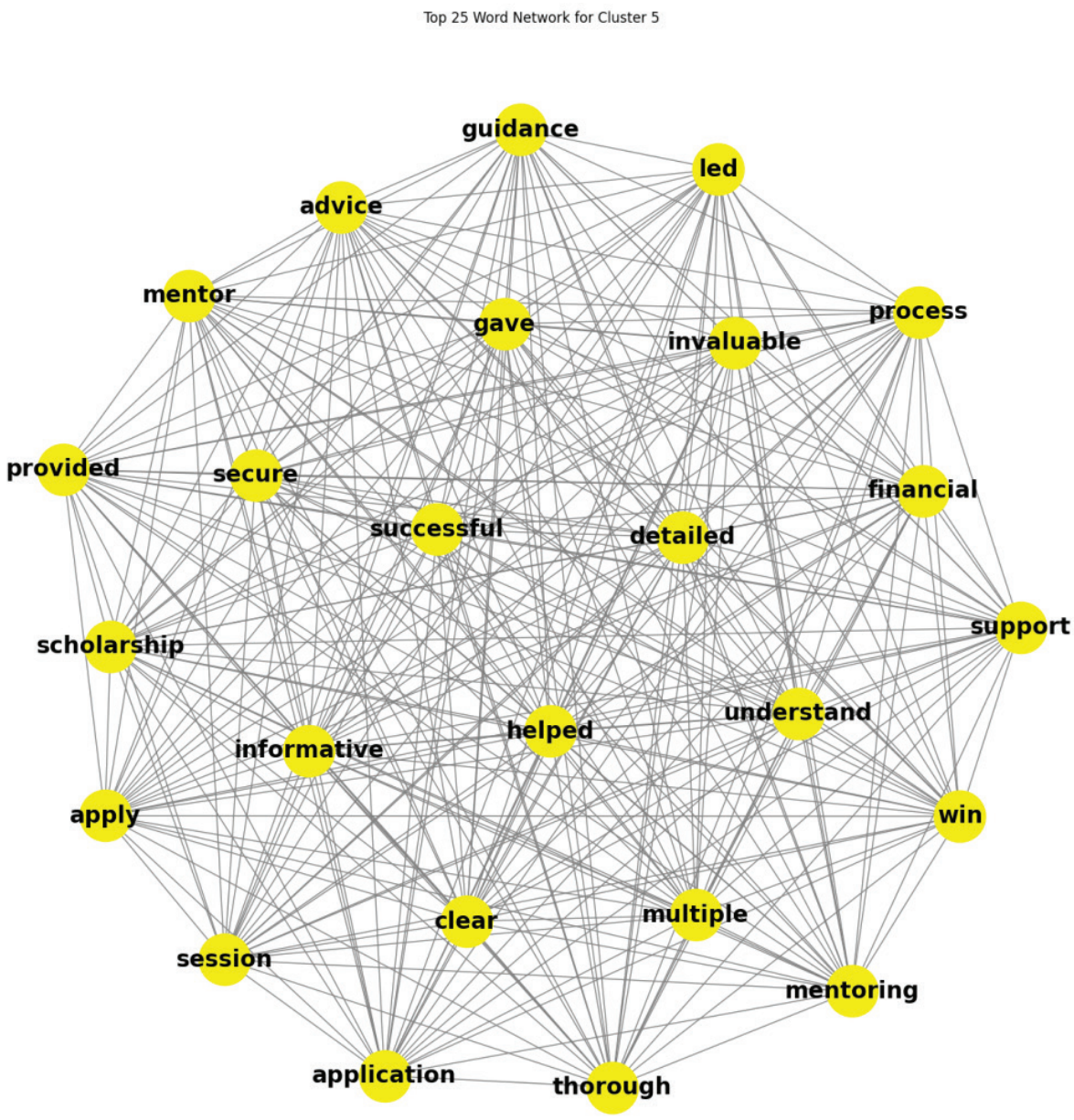

Figure 17. Word network for top 25 words of cluster 5.

success is covertly based on mentors' effectiveness in linking students to resources. Unsure of where to get funds, learning steads its pace.

A number of 35 students have published in prominent journals. With professors' help, these students investigate novel, worth-while questions. One reason they were successful was they received support early in the process. Setbacks provided opportunities to consult about study design and analyses. Others went through drafts before submitting their proposal. Despite modest participation, the results seem promising in contributing to academic productivity. Through such circuits, autonomy in learning to think is grown. The merit of tailored mentorship stands out in terms of its influence to academia.

Acquiring the mentoring experience, 254 students won awards in project competitions ranging from national to global. This demonstrates guidance building on new ideas, teamwork and problem-solving. Students work as a team with constant mentoring. As design and development takes place, mentors guide on how to improve the product. Public recognition demonstrates linking learning to practice. Through support, participants practice and refine skills to where they are tested. Success doesn't come easily

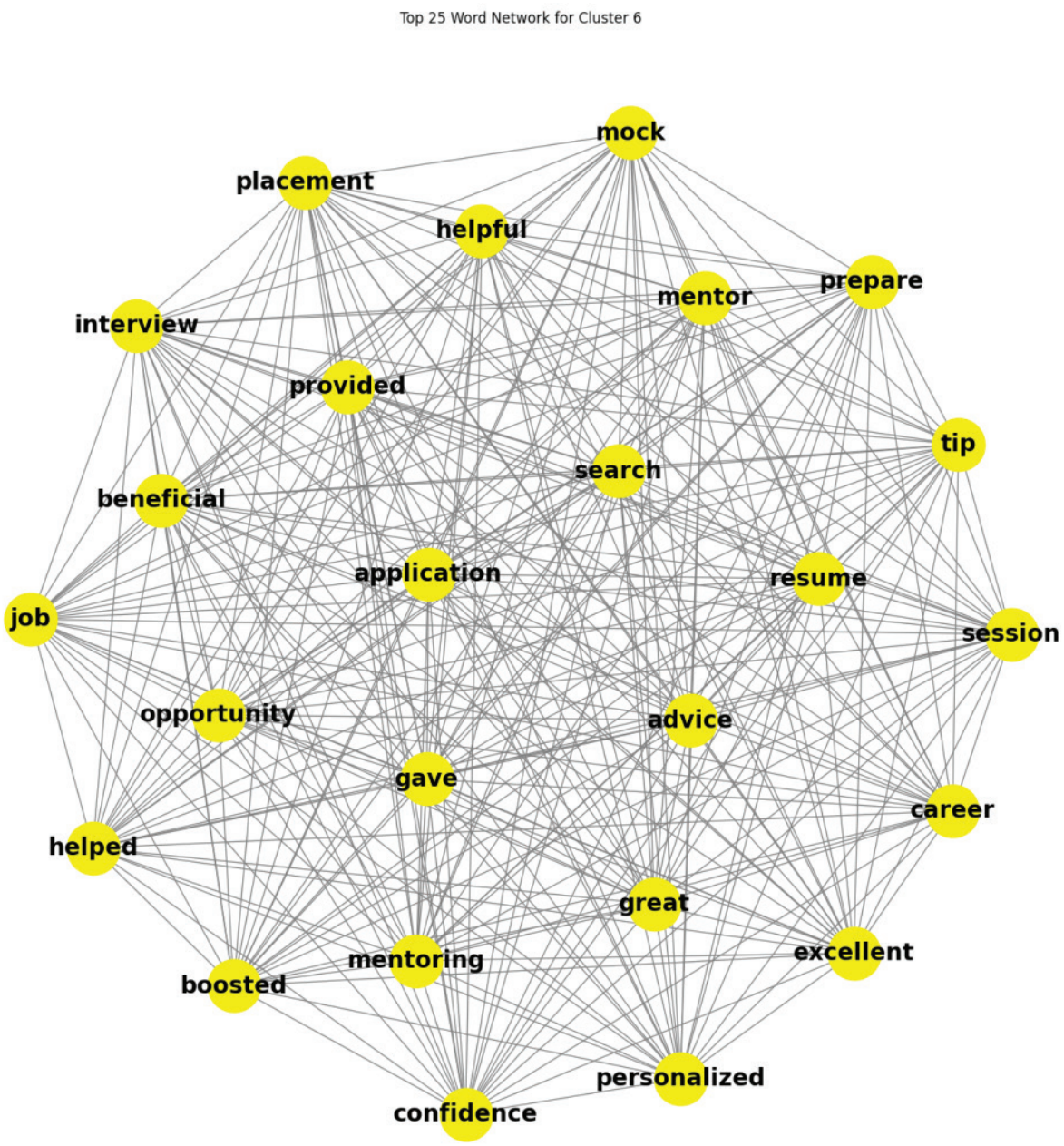

Figure 18. Word network for top 25 words of cluster 6.

but is the culmination of many days of trial and improvement. Globally, success like this demonstrates excellent preparation and confidence.

While effective, supporting students in engineering is tricky. Time and effort are critical, Akili noted in 2014 - guidance is most effective when undiluted, but not if time-limited [24]. Sometimes it's not smooth sailing: online advice altered situations during the pandemic, as Speer, Lyon and Johnson found later [25]. Remoteness offered flexibility, but eroded people's connectedness. What worked for some was "far away" to others Research on mentoring in engineering education shows its importance to student success. Mentoring from peers and/or teachers, and/or more real-life project work, leads to improved grades, increased student confidence and industry readiness, and retention, especially of disadvantaged students. Despite this, there are challenges with maintaining support that caters to all students' needs. Future research needs to explore new mentoring strategies, and their impacts on learning outcomes.

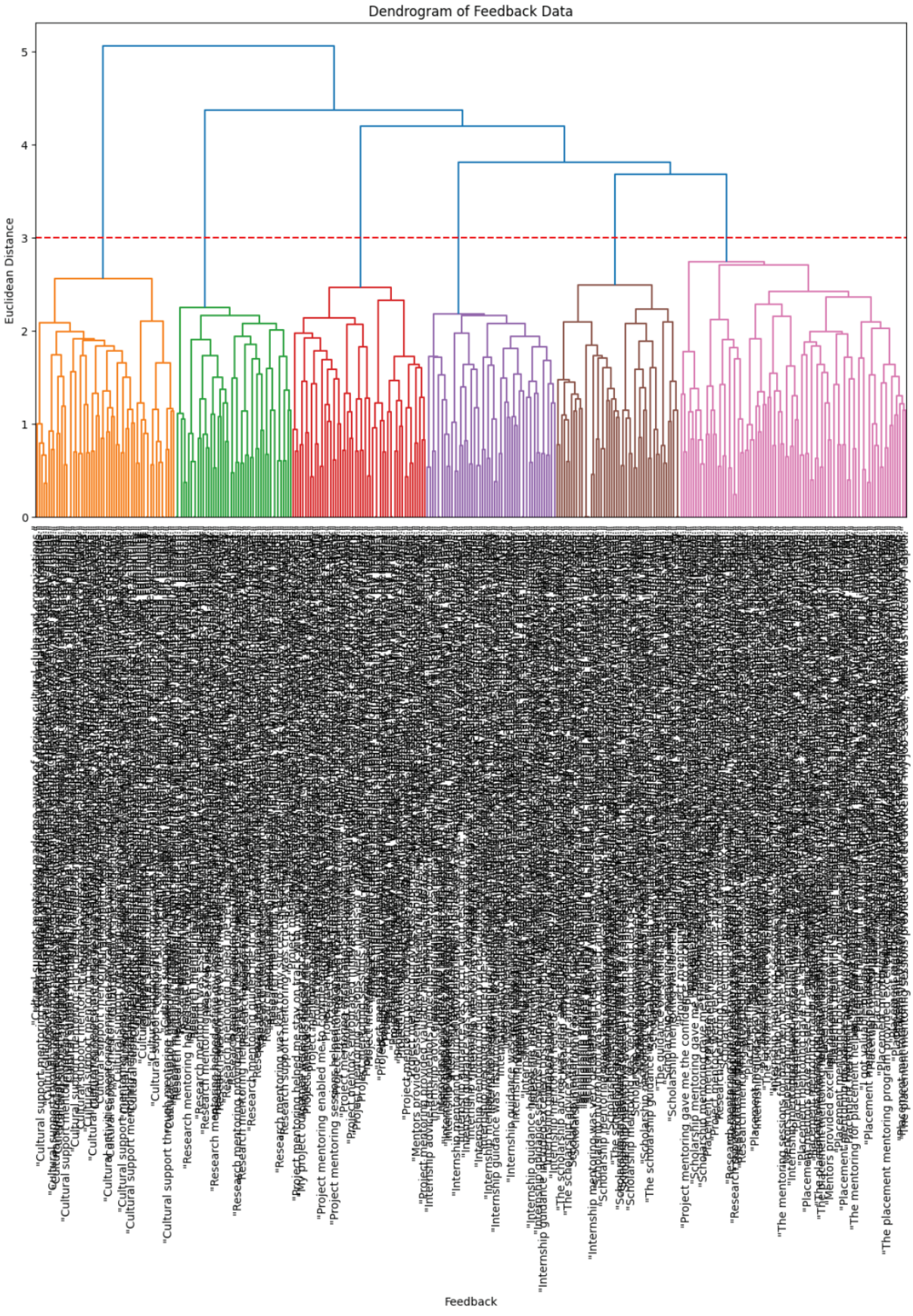

Figure 19. Dendogram for finding out optimum clusters.

Table 1. Optimum mentoring clusters

Sr.No.	Method	Evaluation Criteria	Number of optimum clusters
1	K Means	Davies-Bouldin Index, Calinski-Harabasz Index, and Within-Cluster Sum of Squares (WCSS).	6
2	DBSCAN	dendrogram	6
3	Hierarchical Clustering Analysis	dendrogram	6

Table 2. Mentoring sessions and number of students benefited

Sr. No.	Guidance through Mentoring Sessions	Number of students benefited
1	Internship	1756
2	Placement opportunities	1127
3	Higher education counseling	563
4	Cultural program award	786
5	Various scholarship schemes	259
6	Publications in reputed journals	352
7	Patents/ Copyrights	225
8	Participation in national/ international events	263
9	Awards in national/ international project competition other than academics	254

CONCLUSION

A six-cluster solution of the mentoring text responses was identified through K-means analysis revealing key themes. Supported by a silhouette score of 0.7985, and the Davies-Bouldin, Calinski-Harabasz and WCSS scores. The number of groups was varied - six was chosen because it demonstrated greater cohesion between members of the groups, and greater separations between groups. From the experience of mentoring, these clusters resonate with some of the important aspects known about the program. This provides some basis to choose this grouping. One approach to understanding mentoring is through these six groupings, which cover different factors such as skill development, employability skills, resources offered by the university, comments and feedback on work and study support as well as award advice. Beginning with word clustering and real feedback, clusters held together well - the different categories remained distinct, and made sense. There was the following sentiment analysis.

- Positive feedback: 84.56%
- Neutral feedback: 8.66%
- Negative feedback: 8.77%

There were positive feedbacks from most of the members, suggesting the mentoring program is effective. But a few identified problems that need to be addressed, particularly with regard to personalised support rather than "one size fits all".

Limitations and Future Directions:

We found results more or less consistent across methods. However, some ideas still end up in several clusters - not a failure, but an indication of the diversity of students' views.

A future direction is to try better grouping techniques such as topic modelling (LDA) or embedding (BERT). Using these, groups might better capture student experiences. Rather than a simple list, insights could emerge that reveal true differences in mentor interactions. And complexities in student experience may be highlighted with finer sorting of responses. These fine-tunes might encompass information ignored by more simple models. This can be achieved by fitting response characteristics to appropriate methods.

A further step up is to check a range of sentiment tools against methods of cross-validation - confirming these results. A composite view of mentoring feedback obtained through quantitative data, valid observations and sentiment provides greater clarity. The findings here suggest changes that have the potential to impact on mentoring. When strategies align to insights, programs have a greater chance of growing in responses to diverse student needs. Growth means more than form; it stems from support in line with individual journeys.

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