



Research in Engineering Education Symposium (REES)
Regional Conference in Engineering Education (RCEE)
& Research in Higher Education (RHed)
September 29 – October 3, 2025
Johor, Malaysia



Automating Thematic Analysis of Student Assessments: A Proof-of-Concept Study of Growth Mindset Reflections

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ABSTRACT

BACKGROUND & CONTEXT

Large language models (LLMs) offer the potential to analyse large volumes of qualitative data easily. This proof-of-concept study explores whether this potential is realisable, by analysing students' reflections on their growth mindsets (Dweck, 2006), a predictor of student learning and capacity for lifelong learning, which educators have struggled to teach (Yeager & Dweck, 2020).

PURPOSE OR GOAL

While we eventually aim to understand the relationship between teaching interventions and growth mindset acquisition, this study tests the feasibility of employing an LLM to identify relevant analytic categories, and content analyse text for those categories.

APPROACH OR METHODOLOGY

In the subject Creative Innovative Engineering (CIE) at the University of Melbourne, engineering students write seven reflections of about 750 words on a topic of their choice. In week six, many reflect on their in-class discussion of ways in which they do and don't have a growth mindset. They generally discuss personal barriers to a growth mindset, and strategies for overcoming them. We use an LLM to select the reflections discussing growth mindset from a sample of 533 week 6 reflections, describe the barriers and strategies, and quantify them.

OUTCOMES

This study demonstrates the efficacy of the tools we have been developing and the feasibility of our methodological approach. In addition, our analysis demonstrates the sorts of results that are possible, and provides interesting, if preliminary, insights.

CONCLUSIONS

This study points towards exciting methodological possibilities for generating insights that will improve engineering education.

KEYWORDS

Growth Mindset, AI-assisted data analysis.

Introduction

The advent of AI Large Language Models (LLMs) creates the potential to analyse vast quantities of text with ease. If realised, researchers will be able to combine the rigour of quantitative analysis with the nuance, generativity, and contextualisation of qualitative research. However, the technology is immature, and the tools and methods are nascent. This study tests the feasibility of this approach.

While there is a wealth of scholarship on how and why a growth mindset can be valuable, educators have had mixed success helping students to develop one (Yeager & Dweck, 2020). Our broad conjecture is that we can improve outcomes by understanding how students experience those interventions. Creating Innovative Engineering (CIE) (described below), treats growth mindset acquisition as a transformative learning problem (Mezirow, 1997) which we facilitate through multiple interventions over the semester. This study considers the relationship between one key intervention – an in-class small group discussion in week six around situations in which students do and don't exhibit a growth mindset – and a central pedagogical tool – the use of reflective essays to help students personalise and embed key concepts. It does so by using an LLM to analyse the content of those reflections.

The CIE Context

This study examines student reflections in CIE, a subject taught at The University of Melbourne, to increase the employability of its engineering graduates. In that subject, teams of 4-6 students study a strategic challenge posed by an external sponsor and propose an innovative response. This team project creates a platform for the core teaching objectives: identity transformation around five core ideas: 1) a growth mindset (Dweck, 2006) 2) the idea that a professional's job is to create value for others and that we solve technical problems in the service of that, 3) the value of actively seeking opportunities rather than expecting others to present them to us, 4) the idea that professionals succeed by collaborating with others, and 5) the value of using ethics to guide professional decisions (see also Cebon et al., 2025).

As part of their assessment, students write seven reflective essays of up to 750 words on topics of their choice, so long as it is related to the subject in some way and associated with an emotionally-triggering event. Students describe the event, analyse it, and propose next steps in response to what they have learned. They then exchange feedback with a peer (in addition to receiving formal feedback). We emphasise reflection so strongly because most engineering students need several attempts to master this very valuable professional skill, and because emotion-driven reflections lead students to focus on, personalise, and embed concepts that are important to them.

There are four times in the semester when a significant proportion of students write about their fixed/growth mindset. Those who do so on any of these occasions, and then receive feedback from a peer, connect their growth mindset (or lack thereof) to live learning challenges, and do so through an intrinsically social and collaborative process (Campbell et al., 2021; Murphy & Dweck, 2010). In contrast, typical growth mindset interventions in universities have been criticised for being short-term, individually focused, and disconnected from disciplinary learning (Broda et al., 2018; Campbell et al., 2021; Sisk et al., 2018).

Data Coding with Large Language Models

LLMs are advanced artificial intelligence (AI) models capable of reading and generating text with apparent comprehension. Recent research has demonstrated the potential of LLMs to support qualitative analysis, showing promise for thematic coding of large datasets using established theoretical frameworks (De Paoli, 2023; Mathis et al., 2024). LLMs can process substantial text volumes consistently without the fatigue or coding drift that human coders experience, while maintaining standardised application of theoretical criteria. This efficiency makes them well-suited for our methodological exploration of applying CPM to student reflections like we do in the current study. Notwithstanding, LLMs are not actually intelligent,

and so are vulnerable to making both systematic and random errors that need to be managed carefully to ensure rigour.

While prior studies have sought to use LLMs to conduct broad thematic analyses of large corpora of data, we aim to conduct much narrower analyses across large, repeated datasets. That is, we are interested in conducting data analyses in which we have a well-defined unit of analysis (a student reflection in this case), that we can treat (analytically) the same way as a quantitative researcher would treat a survey. We aim to use binomial statistics to analyse 1) the categorical coding from the LLM, alongside 2) demographic data (gender, course of study, nationality, etc.) and 3) temporal data (location of the document in the semester). Over time, we will build a dataset and a set of analyses that capture the learning journey of ~1000 students across the semester, through seven reflections, seven peer-feedback documents, and a final essay, and links it to their demographic attributes. By using these methods, we will be able to conduct nuanced analyses of large populations of students. Previously, this sort of research would have been prohibitively expensive.

Such a project requires significant effort beyond typical qualitative analysis. These include 1) designing and developing the IT tools that can conduct the analysis efficiently but does not produce unwanted outcomes (particularly a) hallucinations where the LLM codes one reflection on the basis of the content of another, or b) failing to code individual reflections thoroughly), 2) a method for deciding which concepts to code for (particularly, how to combine theory-driven (Etic) concepts with emergent (Emic) concepts (Pike, 1956) while maintaining appropriate conceptual separation between concepts), 3) constructing prompts for the LLM that will reliably code for individual concepts without producing unacceptable type 1 errors (coding a document as containing a concept which it doesn't) or type 2 errors (failing to code a document as containing a concept which it does), and 4) a method for efficiently assessing the reliability of the coding and improving the prompts. This study does not report on all these efforts.

Problem Statement

Specifically, we ask the following questions:

1. Can we use an LLM to identify a set of Emic concepts within a corpus of reflections?
2. Can we use an LLM to code those reflections for those concepts?
3. Can we produce summary statistics and perform a demonstration analysis with the results?

Research methods

The Intervention

After priming earlier in the semester, the concepts of a “fixed mindset” and a “growth mindset” are first introduced explicitly in week six through curated readings and video preparation materials, a brief introduction in class, a small group discussion where students talk about situations in which they do (and don't) exhibit a growth mindset and then the revelation by the instructor that “most people believe they have a growth mindset but very few people do”. This statement both triggers some students to write about growth mindsets and allows them to give themselves permission to acknowledge the challenges they face. In their reflections, those students generally draw on their broader student and life experience and often link it to the small-group discussion of Karpman's drama triangle (Karpman, 1968) (another topic that week), or both.

Data

Between 2017 and 2024, approximately 2,300 students complete CIE. Of those, approximately two thirds have given us permission to analyse their assessment for our research, in accordance with our ethics approval. In the early years students wrote 10 reflections and peer responses of unlimited length. This was progressively reduced, and by

2023 they were writing seven reflections of up to 750 words. These reflections accounted for 22.5% of total marks for each student. In this study, we analyse all the reflections for which we had permission from the years 2020-2024 (533 reflections). All reflections were anonymised as part of the analysis process.

Data Analysis

Our research questions required us to analyse the data twice. First, we needed to identify the Emic concepts by identifying the entire corpus of reflections (category identification). Then, we needed to inspect each reflection to see whether or not it contained each of the concepts that we had identified (coding).

Category Identification

1. For each of two semesters (2020-S2 and 2023-S1), we aggregated all the week-six reflections into one text file, separating them with xml tags.
2. We uploaded the first file to Anthropic's Claude Sonnet 3.5 LLM, deployed on the authors' institution's Spark LLM platform, provided the LLM with appropriate definitions, and asked it to identify the reflections that talked about a growth mindset or a fixed mindset (to exclude the reflections that talked about something else).
3. We then asked it several questions about the subset and gave it permission to infer answers from the text.
 - a. The sorts of things people talked about.
 - b. Barriers to acquiring a growth mindset that authors discussed. (It identified 12.)
 - c. Reasons why people hold onto a fixed mindset. (It identified 15.)
 - d. Strategies to overcome these barriers to a growth mindset and/or things that hold them in a fixed mindset. (It identified 18 strategies.)
 - e. Finally, we asked the LLM to tell us about the reflections that talk about relationship between the drama triangle and fixed mindsets. (It identified ten key points.)
4. We repeated the process for the second file in a new LLM session (15 barriers, 20 reasons to hold onto a fixed mindset, 18 strategies, 10 points about drama triangles).
5. We aggregated all the barriers the LLM had identified into one list, and all the strategies into another. As expected, these lists overlapped significantly. Two of the authors then reduced the lists to a reasonable-looking set of distinct concepts.

Category Coding

We then asked the LLM to inspect each reflection and tell us which concepts were present. Because a Retrieval Augmented Generation (RAG)-based approach produced unacceptable hallucinations (analyses based-in part on reflections other than the one under-consideration), we wrote software which bypassed the user-interface and addressed the LLM directly. The user would pre-process a batch of reflections to anonymise them and convert them to a text document, and upload them and the prompt to the cloud. For each reflection, the LLM would initiate a new session, apply the prompt to the content, and create a text file that contained the results. The user would download the batch of text files and then post-process them to insert the results into a spreadsheet

Prompt Development

Each prompt contained a list of concepts and asked the LLM to inspect each reflection for all the concepts in the prompt. We used appropriate prompt engineering practices, such as giving the LLM a role as a conscientious qualitative researcher and asking it to explain its chain of reasoning.

1. Prompt architecture:
 - a. For each concept, the prompt contained a definition. If the LLM determined that the concept was present in the reflection. If so, we also asked it for:
 - i. its justification for its choice
 - ii. a representative quote.
 - b. The number of concepts per prompt traded off the number of batches we needed to run (@ ~10 minutes per batch of ~130 reflections) against the risk that the machine would forget part of its instructions. On advice from an IT student, we settled on a maximum of five concepts per prompt. This meant that each iteration (on ~ ¼ of the reflections) took about an hour, and the final coding run took ~200 minutes.
2. Definition iteration:
 - a. We developed the definitions for each concept iteratively.
 - b. After each iteration, we would read the quotes and the justifications to determine whether or not the prompt was coding for the underlying concept and would refine the definition accordingly.
 - c. Initially, each prompt contained just the concept and its definition.
 - d. After several iterations, we changed the prompt architecture to give the LLM:
 - i. a definition (see table 1),
 - ii. a set of behaviours it might expect to observe, along with other elaborations of the definition and specific instructions about what to look for, and
 - iii. some exemplar quotes from reflections.

These three parts were explained in the instructions to the LLM and separated by xml tags.

- e. Over time, the prompts for some concepts became narrower and clearer, and the number of reflections coded for that concept declined accordingly. That is, type 1 errors came down to an acceptable level. We suspect that, in the process, there are some reflections that contain adjacent concepts that we didn't code for at all. Also, quite likely, there are some reflections that contain that concept, but which the LLM missed (type 2 errors). Unfortunately, there was insufficient time to test these suspicions. Next steps here are discussed below.
- f. Interestingly, over time, the prompts for other concepts "Growth Mindset", "Fixed Mindset", "Reframing challenges and failures" and "Self-reflection and awareness". diverged. The more we refined the definition to exclude cases, the more cases the LLM included! After nine attempts, each less successful than the one before, we removed "Reframing challenges and failures" and "Self-reflection and awareness" from the dataset, and changed the definitions of "Growth Mindset" and "Fixed Mindset" to a single variable coding for whether or not the reflection contained the text string "Growth Mindset" or "Fixed Mindset". (see discussion).

Final Data Analysis

Once we were satisfied with the definitions, we used the LLM to perform the same steps as would be deployed in a manual analysis, namely:

1. Determine which reflections talked about fixed or growth mindsets,
2. For those reflections, determine the various categories of:

- a. Barriers to moving towards a growth mindset
 - b. Strategies for overcoming those barriers
3. Identify which categories of barriers and strategies are associated with each reflection.
4. Report the results.

To determine which reflections talked about growth mindsets, we applied our growth mindset / fixed mindset prompt to the 533 reflections, as per the procedure above. We eliminated all reflections that talked about neither, leaving 215 reflections in the sample (see table 1).

To identify the barriers and strategies in each reflection we applied the relevant prompts, in groups of five, to ~135 reflections at a time. We aggregated the results and exported them into SPSS for analysis. The definitions (but not the behaviours, elaborations, and sample quotes) for each barrier are presented in table 2, along with the number of reflections (out of 215) containing them. Likewise, strategies in table 3. Finally, to explore whether particular strategies and barriers are associated with each other, table 4 cross-tabulates barriers with strategies and tests whether the number of reflections in that cell differs statistically from the expected number. In order to conduct this analysis, we eliminated barriers and strategies that were coded less than 35 times (to maintain the integrity of the Chi-Squared test) or more than 200 times (as explained above). Statistically significant and highly significant relationships are marked in green, and pink respectively.

Results

Results are presented below.

Table 1: Presence of “Growth Mindset” or “Fixed Mindset”

Presence of “Growth Mindset” or “Fixed Mindset”	Count	Freq (%)
Not Present	316	59.5%
Present	215	40.5%

Table 2: Barriers to a growth mindset identified by students

Growth Mindset Barrier	Definition of the barrier	Count	Freq (%)
Status quo comfort	Status quo comfort means the author has a tendency to adhere to familiar routines or methods, often but not always reinforced by past successes	142	66.7%
Ingrained habits	Ingrained habits mean the author has a tendency to adhere to established thought patterns or behaviours	137	64.3%
Performance Pressure	Performance pressure means the author feels overwhelmed, rushed, or pressured because of external demands for high performance	126	58.9%
Fear of vulnerability	Fear of vulnerability is a fear of the author that others will judge them badly, hurt them, take advantage of them, humiliate them, or undermine them in some way if given an opportunity to do so.	111	51.9%
Uncertainty aversion	Uncertainty aversion means the author has a strong dislike or tendency to avoid ambiguous, unpredictable situations. They dislike the ambiguity or unpredictability itself, not other things associated with the situation.	109	51.2%
Fear of Failure	Fear of failure is the fear of the author of negative consequences, judgement, or loss of credibility if they make mistakes or fail to meet expectations.	107	50.7%
Lack of self-efficacy	Lack of self-efficacy means that the author believes they lack the inherent capacity in their core self to learn certain skills or subjects or areas of knowledge. It is not ephemeral, like lack of motivation.	91	43.5%
Identity inertia	Identity inertia means that the author has a tendency to cling to their current identity or self-concept	91	42.7%
Defensiveness	Defensiveness means that the author has difficulty in hearing, accepting, or and learning from feedback on your behaviour.	86	40.2%
Perfectionism	Perfectionism means the author wants to be or do something that is perfect without faults and up to the best of their ability, setting excessively high performance expectations of yourself, combined with an intolerance for mistakes or perceived failures	84	39.3%
Fear of Judgement	Fear of judgement means the author experiences stress or anxiety about how others will perceive them, as a person, through evaluations of their actions, words, or appearance, but not their performance (which is captured by fear of failure).	67	31.8%
Lack of grit	Lack of grit means the author has a tendency to give up, instead of investing additional effort, when confronted by setbacks in the pursuit of goals	61	28.6%
Comparison to others	Comparison to others means the author focuses on the qualities, behaviours, or achievements of another person or group (peers, siblings, parents and relatives, or those perceived as more (or less) talented/successful) as the measure to evaluate themselves. The comparator is never themselves at another time or place.	60	28.0%
Expectation pressure	Expectation pressure means the that the author feels pressured to meet perceived cultural, societal or family standards or is anxious about failing to meet these expectations	57	26.6%
Lack of grit	Lack of grit means that the author avoids sustained effort and persistence in the face of challenges	51	24.1%
External validation	External validation means that the author relies strongly on extrinsic approval, encouragement or recognition evaluate the quality of my work, and/or to evaluate their self-worth, rather than basing their evaluation on an intrinsic understanding of themselves.	51	23.8%
Skill delusion	Skill delusion means that the author believes that true talent or ability should manifest without significant effort or struggle. It does not mean that others believe the author should be able to do things without struggle.	35	16.5%
Fixed Mindset Education system	A fixed mindset education system is an education system that encourages students to develop a fixed mindset. The education system that has contributed to a fixed mindset must be specifically mentioned rather than being implied.	27	12.7%
Exposure to diversity	A lack of exposure to diversity means the author has not encountered or interacted with groups or individuals who differ from them, such as	26	12.3%

	in relation to characteristics like gender, professional discipline, social class, racial or ethnic background, religion, culture, cognitive style, personality, or others. The author's writing must explicitly link their experience to one or more forms of difference.		
Procrastination	Procrastination is the tendency of the author to actively avoid immediate tasks, or distract themselves with alternative tasks, as a way to manage or avoid something, such as anxiety. It is not a failure to do something because of forgetting.	26	12.1%
Time Pressure	Time pressure means that the author feels overwhelmed, rushed, or pressured because of lack of time	25	11.7%
Growth mindset ignorance	Growth mindset ignorance means a lack of awareness or understanding by the author about the concept of growth mindset and its potential benefits for learning, personal development, and overcoming challenges. It does not mean being aware of the concept but failing to have applied it to themselves.	10	4.7%
Machismo	Machismo means the author has an exaggerated sense of self-reliance and pride, typically associated with masculine stereotypes, that views seeking assistance as sign of weakness or inadequacy. There is some behavioural indication of its presence.	9	4.2%

Table 3: Strategies to develop a growth mindset identified by students

Development strategy	Definition of strategy	Count	Freq (%)
Self-reflection and awareness	A strategy of self-reflection and awareness is a decision to consciously engage in a process of self-reflection as a deliberate practice. Self reflection is a process of observing and analysing one's feelings and behaviour to develop insights and awareness of the possible reasons behind them. To be a strategy, the author must link self-reflection and awareness to their future behaviour, not the current or past behaviour.	214	100.0%
Reframing challenges and failures	A strategy of reframing challenges and failures is a decision to consciously engage in a process of reframing challenges and failures as a deliberate practice. Reframing challenges and failures means actively, consciously working to change one's perspective or interpretation of a challenge or failure, or approaching a problem from different angles. Often this includes a commitment to be more positive and growth-oriented. To be a strategy, the author must link reframing of challenges to their future behaviour, not the current or past behaviour.	199	93.0%
Resilience	Resilience means the ability to withstand, adapt to, or recover quickly from difficulties. these difficulties might be practical or emotional.	163	75.8%
Continuous learning	A strategy of continuous learning is a conscious decision to engage in continuous learning as a deliberate practice. Continuous learning means engaging in an ongoing process of intellectual or skills acquisition or development. it can also mean continuous refinement of existing skills, either personally or professionally. The author must invoke learning as a strategy for their future behaviour. It is insufficient for them to indicate that they have learned something.	151	70.6%
Embracing discomfort	embracing discomfort means being willing or even excited to encounter difficult or uncomfortable situations or emotions. The author must explicitly or implicitly refer to the associated emotional challenges. For example, it is not sufficient to say they will embrace failure unless they also reference the negative feelings or identity threats they associate with failure explicitly or implicitly.	148	69.2%
Mindfulness	Mindfulness is a cognitive practice of being aware of the present moment while acknowledging and accepting one's thoughts, feelings, or physical sensations in the present	125	58.1%
Process-oriented goals	A strategy of process-oriented goals is a decision to consciously engage in the setting of process-oriented goals as a deliberate practice. process-oriented goals means goals that focus on the steps or actions required to reach a goal, emphasising these steps rather than the final outcome. These goals may be short-term, focused or	120	56.1%

	controllable. the focus of these goals is on the habits or behaviours needed to achieve results		
Positive self-talk and affirmations	Positive self-talk means having an optimistic, encouraging, or positive internal dialogue involving speaking to oneself with kindness. This positive self-talk might involve affirmations, which are positive statements designed to be encouraging or supportive.	116	54.7%
Cultivating curiosity	Cultivating curiosity means developing one's eagerness to learn, explore, or be open to new experiences or perspectives. This is an active strategy, and is not just the acknowledgement of interesting opportunities that have come the author's way.	115	54.0%
realistic goals and expectations	Setting realistic goals and expectations means having objectives that are possible to achieve with one's current resources, circumstances, and time allotment. realistic goals and expectations are based on common sense, experience, or likelihood of what will occur. they also acknowledge limitations or potential obstacles or difficulties.	84	39.1%
Seeking and accepting feedback	Seeking and accepting feedback means taking a proactive approach to seeking the opinions of others on one's behaviour or performance, while also being receptive to those opinions.	76	35.3%
Support and mentoring network	Having a support and mentoring network means having people around oneself who provide practical or emotional support, especially during difficult or challenging experiences. This support might involve offering advice, assistance, or encouragement, helping each other to think things through, or helping each other process their emotions. In the case of mentoring relationships, this could also involve support for one's personal and professional development through guidance, advice, or constructive feedback.	41	19.1%
Practicing gratitude	practicing gratitude means appreciating or being thankful for what one has, the good things in one's life, or the positive words, influence, or actions of others.	34	16.0%
Time management	Developing good time management means effective or productive use of one's time.	15	7.0%
Celebrating others' successes	Celebrating others' successes means that the author believes that personal success comes from one of two routes. Either, one can learn by observing others and learning from their successes, or that success comes through the support of others, and support from others is engendered by supporting them.	10	4.7%

Table 4: Cross-tabulation of Barriers to a Growth Mindset and Strategies for overcoming them.

		Cultivating curiosity	Embracing discomfort	Mindfulness	Seeking and accepting feedback	Support and mentoring network	Positive self-talk and affirmations	Practicing gratitude	Realistic goals and expectations	Resilience	Continuous learning	Process-oriented goals
Comparison to others	Count	30	43	38	21	12	35	11	29	47	39	33
	P-value	0.489	0.665	0.362	0.922	0.759	0.537	0.58	0.089	0.643	0.236	0.873
Defensiveness	Count	58	63	52	42	16	50	15	29	72	69	50
	P-value	<.001*	0.325	0.617	<.001*	0.979	0.356	0.619	0.174	.034*	.014*	0.583
Expectation pressure	Count	25	47	35	17	8	38	9	29	51	40	31
	P-value	0.093	.010*	0.537	0.295	0.251	.019*	0.992	.036*	.005*	0.918	0.928
External validation	Count	22	42	27	16	11	35	9	26	43	37	23
	P-value	0.096	.018*	0.364	0.529	0.546	.015*	0.599	.049*	0.1	0.721	0.07
Fear of Failure	Count	47	78	63	39	21	66	23	41	91	68	60
	P-value	.003*	0.114	0.861	0.781	0.942	.019*	.029*	0.869	.002*	0.062	0.793
Fear of Judgement	Count	30	52	37	26	14	42	10	31	52	47	40
	P-value	0.059	0.053	0.537	0.5	0.714	0.055	0.8	0.132	0.68	0.795	0.334
Fear of vulnerability	Count	47	92	71	38	23	77	17	52	96	71	61
	P-value	<.001*	<.001*	0.087	0.796	0.429	<.001*	0.986	.018*	<.001*	.028*	0.732
Identity inertia	Count	44	70	57	34	19	53	13	40	75	54	47
	P-value	0.196	.028*	0.312	0.57	0.498	0.246	0.552	0.197	0.06	.005*	0.324
Ingrained habits	Count	69	98	81	52	27	72	20	55	106	89	83
	P-value	0.257	0.18	0.861	0.26	0.641	0.83	0.509	0.636	0.546	0.11	0.055
Lack of grit	Count	27	46	37	16	15	37	12	24	48	45	34
	P-value	0.097	0.123	0.711	0.082	0.169	0.174	0.343	0.943	0.568	0.345	0.921
Lack of self efficacy	Count	41	75	58	34	23	62	17	42	78	62	45
	P-value	.010*	<.001*	0.167	0.604	0.07	<.001*	0.417	0.072	.006*	0.567	0.106
Perfectionism	Count	33	63	52	24	16	51	12	38	66	56	43
	P-value	.001*	0.158	0.405	0.088	0.914	0.093	0.641	0.149	0.507	0.38	0.34

Performance pressure	Count	57	91	80	47	26	71	24	53	104	78	72
	P-value	.004*	0.154	.049*	0.513	0.511	0.337	0.126	0.314	.005*	.001*	0.544
Skill delusion	Count	15	25	17	13	10	17	5	15	29	22	18
	P-value	0.174	0.804	0.215	0.811	0.13	0.366	0.789	0.669	0.295	0.449	0.657
Status quo comfort	Count	76	96	78	50	27	73	21	52	105	100	78
	P-value	0.803	0.729	0.169	0.84	0.902	0.378	0.508	0.32	0.43	0.89	0.888
Uncertainty aversion	Count	50	82	66	36	21	61	12	42	86	73	58
	P-value	.031*	.024*	0.571	0.495	0.852	0.338	0.053	0.894	0.32	0.382	0.468

Note. Each cell shows frequency count (p-value). *N* = 215 students who discussed growth mindset concepts in their reflections. Barriers with count < 30 were excluded, to avoid cells with counts of less than five. Two strategies were excluded because the coding was not valid.

Table 2 shows the barriers identified by the students in their reflections. As can be seen, the most common barriers are “Status quo comfort” and “Ingrained habits”. Not surprisingly, these two variables are closely related. They are followed by performance pressure, fear of vulnerability, uncertainty aversion and fear of failure. While the first two do not require any agency, or terribly much insight or emotional self-knowledge, the next four speak strongly to the emotional journeys of students through our classrooms and are likely to be a source of significant insight as we progress the research.

Table 3 shows the strategies students propose to adopt to overcome these barriers. In addition to the reflection and reframing challenges (which should be discounted for the reasons presented above) the principal learning strategies are building resilience, engaging in continuous learning, embracing discomfort, practicing mindfulness, adopting process-oriented goals, engaging in positive self-talk, and cultivating curiosity. Once again, it is encouraging to see students focusing on strategies to adopt a growth mindset (i.e. improve their ability to learn) that are realistic changes and in which they are purposive agents.

Table 4 shows that the distribution of barriers and strategies is not random. The results broadly accord with our expectations. For instance, students which articulate a fear of being vulnerable as a barrier to a growth mindset are much more likely to propose strategies that address this: cultivating curiosity, embracing discomfort, positive self-talk and affirmations, setting realistic goals, building resilience, and continuous learning.

If we look at specific reflections, we can see these connections. For instance, student 186, who identifies performance pressure as a barrier and resilience as a strategy links them as follows:

The anxiety I feel around not meeting expectations that I placed on myself can deter me from giving myself 100% to challenges [barrier: performance pressure]... Going forward I am going to be more openminded and optimistic about improving, improvement does not happen in a short period of time, it's a continual journey that embraces challenging tasks and setbacks are part of the process [strategy: resilience]

Likewise, student 3 links fear of vulnerability to strategy of embracing discomfort:

Additionally, as an international student and a non-English native speaker, the CIE journey makes me feel like it is a heavy burden because sometimes it is hard for me to get some valuable points in lectures, meetings, and interviews. I just want to stay in my 'comfort zone' [barrier: fear of vulnerability]... From now on, I should remind myself all the time, do not stand in the 'comfort zone' anymore, try my best to step into the 'growth zone'. I will embrace all the challenges as opportunities to improve myself for the rest of the CIE journey and future life [strategy: embracing discomfort]

Discussion and Conclusions

This proof-of-concept study aimed to see whether (1) we could use an LLM to identify a set of Emic concepts within a corpus of reflections, (2) we could use an LLM to code those reflections for those concepts, and (3) we could produce summary statistics and perform a demonstration analysis with the results. Largely, we have succeeded. However, we note the following ways in which the methodology could be improved:

Iterating Categories and Prompts

As noted above, we were unable to get the LLM to successfully code for three of the concepts: Growth/fixated mindset as a state, and reflection and problem reframing as strategies. In essence the reason for this appears to be that the LLM cannot differentiate between the presence of a concept in the reflection and adoption of that concept as a strategy. Specifically, every reflection has the attributes of a reflection (by definition), most involve reframing a problem as their central insight, and because the author makes their learning explicit, they appear to manifest aspects of a growth mindset. So, the LLM codes for these because the reflection embodies them, even if it doesn't talk about them.

We have no solution for this, yet. However, as a first step, we intend to change our prompt architecture again. Specifically, we intend to try removing the elaborations on the definition and "what to look for" parts of the prompt to a separate section. We also intend to add quotes that illustrate what does NOT count as an example of the code.

Second, as also noted above, the progressive refinement of our definitions suggests the need for some additional steps in construct creation. Specifically, there is a need to alternate between two activities, until results are satisfactory:

1. Loading all the barrier (or strategy) definitions into a single prompt and ask the LLM to analyse a set of reflections to identify any barriers (or strategies) that are present in the reflections but not in the prompt. Then, create new prompts for additional barriers (or strategies) or edit the prompt for an existing barrier (or strategy) to incorporate the additional cases.
2. Create tables like table 4, but with barriers or strategies on both axes (equivalent to a correlation matrix). If the association between two barriers or strategies is very strong, either eliminate one by consolidating the variables, or differentiate them to separate the concepts.

Third, where appropriate, aggregate narrow concepts with only a few cases into larger concepts. To do this, you need to start imposing a theory on the data. We expect that doing so is likely to result in a significant recoding of many of the concepts in the paper. In fact, one of the promises of machine-based coding, is that it is not terribly difficult to recode the same data for similar concepts through different theoretical lenses.

Fourth, the exercise showed how much we take for granted when we code manually. In the first two iterations, we gave the LLM definitions that seemed perfectly reasonable, and it selected many cases that satisfied the definition, but didn't match the concept. Machine coding forces researchers to be much more explicit.

Finally, since drafting this paper, Anthropic released Sonnet 4.0. We have observed a step-change in quality when we use it create draft reflection feedback. We expect a similar impact on the next iteration of this project.

Growth Mindsets and Student Learning

These results are preliminary at best. Notwithstanding, they start to point to exciting possibilities about teaching students to be better learners. As noted above, a portion of students are clearly showing significant insight and agency in their reflections. However, this is only in week six, so they have only written about half of the required reflections. We can expect that when we start analysing later weeks, we will see greater reflective skills, and with that, stronger emphasis on emotional drivers and goals, and the strategies that are starting to be emphasised strongly here.

As noted in the introduction, the concept of growth mindset is introduced in week six of the course, and there are three other occasions when students write about it (two other reflections and a final essay). There is also the feedback that each student gives to a peer on their reflection. These will all be incorporated into future developments of this study.

Future Implications

Our findings point to wider implications for teaching and learning in engineering education. This approach could be taken from learning into teaching. The systematic identification and categorisation of student attributes, such as growth mindset barriers and strategies, though automated analysis, may enable more targeted educational interventions. This methodology could allow educators to identify clusters manifesting specific attribute patterns and develop corresponding personalised teaching and learning. As a preliminary example of this, we have observed that some Chinese students demonstrate different critical thinking styles when giving feedback to peers on their reflections. This is predicted by theory (Nisbett, 2019) but we had not observed it with an overt test (Meyer, 2015). This led us to change the way we discuss and evaluate critical thinking. In the realm of growth mindsets, we imagine differentiated instructional approaches, such as providing resilience-building activities for students expressing performance pressure or discomfort-tolerance exercises for those reporting vulnerability fears. Continuous tracking of students' mindset patterns through reflective writing could alert educators to intervention needs and suggest targeted strategies matched to individual barrier profiles.

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Acknowledgements

This research was conducted in accordance with University of Melbourne Ethics approval #30017.

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