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Modelling reflection in descriptions of design practice using linguistic inquiry

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Abstract: Reflection plays a vital role in the development of designers, enabling them to evaluate their experiences, enhance their learning, and aid professional growth. This research analysed reflections of 56 design students, as part of graded coursework, using content and dictionary-based approaches (LIWC). Building on an existing model of reflection with eight components – experience, belief, difficulty, perspective, feeling, learning, intention, and descriptive – we identify, using descriptive statistics, the linguistic features associated with each component and correlate these to grades achieved. We distinguish two types of reflections associated with higher grades: those emphasizing personal experiences that we term *holistic narrators*, and those that focus on critical self-evaluation that we term *in-depth explorers*. Our results provide insights for design educators, guiding interventions to enhance critical thinking and self-reflection among design students. They also inform the development of automated tools to assess and enhance reflective practice in educational and design settings.

Keywords: reflective practice; design education; linguistic analysis, LIWC

1. Reflection in designing

Reflection is an important cognitive activity for designers that involves looking back on events, analysing, and evaluating them, and forming conclusions for future action. Reflection, according to Dewey (1933), is a continual cycle of experience, observation, conceptualization, and experimentation. Moon (2004) highlights the significance of reflection in experiential learning, emphasizing the integration of experience and reflection to make sense of experiences and develop new insights. She emphasizes the cyclical nature of learning, where experience leads to reflection, which, in turn, informs further action and experience. This holistic approach acknowledges that reflection is not simply a cognitive exercise but also an emotional and embodied process. Schön (1983) focuses on reflective practice in professional domains, drawing a distinction between reflection-in-action as part of designing activity and reflection-on-action to improve professional performance.



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Novice designers and experienced practitioners can benefit from a better understanding of their behaviour when designing, leading to more informed decision-making and continuous improvement in their design processes. By reflecting on their design experiences, designers can identify areas for growth, enhance their design thinking, and develop a deeper awareness of their design principles and values (Schön, 1983). Understanding the reflective practices of design students holds immense value for both design education and professional growth. Adams et al. (2003) emphasize that reflection helps students to get a better understanding of their design process, including constraints, trade-offs, and ethical implications. Mezirow (1991) highlights the significance of critical reflection in design because it allows designers to critically question their assumptions, values, and biases, as well as consider the social and ethical ramifications of their design decisions.

2. Analysing reflective writing

Reflective writing is a valuable tool for improving critical thinking and learning in a variety of contexts, including design education. Writing in a reflective manner encourages self-awareness, self-evaluation, and self-directed learning, which results in improved understanding and sense-making. However, reflective writing, according to Bolton (2010), should be viewed as a type of professional development that requires rigorous evaluation rather than just personal expression. Assessing or analysing reflective writing is critical to ensuring its success as a reflective activity.

Language is, of course, the medium through which we describe our thoughts, emotions, and social relationships. Language structure, and the words we use, conveys information about our personality, cognitive processes, emotional states, and social behaviours. Pennebaker (2011) has shown how researchers can gain insights into the socio-psychological significance of words by studying word choice with linguistic analysis providing a systematic and objective approach to textual data analysis.

It is crucial to highlight that not all types of text analysis fall under the scope of computational linguistics or natural language processing (NLP). Initially, researchers used manual coding and content analysis to assess and classify textual data using well-established coding schemes (Pennebaker, 2011) and methods such as thematic analysis, content analysis, and narrative analysis (Vaismoradi et al., 2013), providing a nuanced understanding of reflective content. Nevertheless, these methods have limitations, including subjectivity, resource-intensiveness, scalability constraints, incomplete analyses, and privacy issues (Ullmann, 2019). While manual coding approaches offer context sensitivity and nuance, combining them with automated or computational methodologies can mitigate their shortcomings (Eichstaedt et al., 2021). Thus, researchers should embrace both manual and automated methods to enhance the depth and breadth of analyses (Crossley, 2020).

There is a growing interest in using machine learning and linguistic analysis to gain deeper insights into the cognitive processes and linguistic aspects of reflective writing. In recent years, the rapid developments in machine learning (ML) and artificial intelligence (AI) have

paved the way for innovative approaches to understanding human behaviour. The developments in computational linguistic analysis have contributed to the creation and development of tools like Linguistic Inquiry and Word Count (LIWC) (Tausczik and Pennebaker, 2010), while ML and AI advancements have played a crucial role in developing tools like Empath (Fast et al., 2016). The approaches that have been used to automatically analyse reflective writing have also been influenced by these developments and can be broadly categorized according to three approaches: dictionary-based, rule-based, and ML-based (Ullmann, 2019).

In the present study we combine two approaches: we first use Ullman's rule-based approach to code reflective writing, and then use LIWC's dictionary-based approach to explore the coded data for linguistic patterns that may result. The work presented here represents initial steps toward developing a linguistic characterisation of design students' reflective writing, which has the potential to benefit both design students and design educators.

3. Eight components of reflection

We use LIWC to study design students' reflections on their own design practice. A central part of this research involves using predefined dictionaries and employing a rule-based approach. LIWC allows us to systematically, quantitatively, and consistently categorize words into predetermined linguistic and psychological categories (Pennebaker & Francis, 1996).

To do this we draw on Ullmann's (2015a; 2019) meta-analysis identifying the components constituting reflection. Ullmann's analysis resulted in a model of reflection comprising eight components – reflection, experience, feeling, belief, difficulty, perspective, learning, intention. The component of 'reflection' from Ullmann's model was not used in the present research due to the difficulty of practical coding. Instead, a new component of 'descriptive' was employed to identify sentences that were non-reflective or purely descriptive in nature. This serves as a baseline for the linguistic inquiry methodology that we go on to use in the research. We feel that Ullman goes further than many other studies in defining the depth and breadth of reflection in reflective writing. The following (except for #8) are the definitions of these components as described by Ullmann (2019):

1. Experience: Description and recounting of personal experiences, highlighting their subjective encounters and narratives;
2. Belief: The expression of personal beliefs, perspectives, or opinions on various topics or issues;
3. Difficulty: Critical assessment of actions or experiences, where challenges, obstacles, or struggles encountered are analysed;
4. Perspective: Consideration of alternative viewpoints or perspectives, indicating an ability to understand different sides of an issue or situation;
5. Feeling: Emotional experiences and expressions, capturing feelings and affective states;

6. Learning: What has been learned or gained from an experience, indicating acquisition of knowledge, insights, or lessons;
7. Intention: Expressed intentions or plans for future actions or behaviours.
8. Descriptive: Text that is purely descriptive or non-reflective; a straightforward description without any critical assessment.

The last component (#8: Descriptive) above replaces Ullman's original "Reflection" component. We made this change as we deemed coding reflective text as "reflection" to be of limited use when the goal was to identify finer nuances within reflective text. We also observed in the essays sentences that were purely descriptive and non-reflective and decided to use the #8 slot to describe such text instead.

By using this model of 'reflection detection' as a guiding framework, we attempt to 'fit' the pre-defined LIWC dictionaries to these reflective components in further deepening our understanding about the concept of reflection. We do this in an educational context by analysing written reflections produced by students as part of a course on design theory and methodology. Our research indicates tentative correlations between student grades and the linguistic content of reflections. This suggests it may be possible to develop more automated systems for assessing reflective activity in designing.

4. Methodology

4.1 Data collection

A master's course in Design Theory and Methodology (DTM) at Delft University of Technology provides the context and data for this study. DTM is a compulsory course for all master's design students – approximately 350 students per year (60% Dutch, 40% international). All students have experience of designing. The course helps ground students' understanding of design methods and design theory into their own practices. Given that the program is at the master's level in a university setting, we assume that all students possess a baseline level of English proficiency.

Part of the final assignment for the course was a 300-word reflection, requiring students to reflect on their own design practice in relation to a chosen essay topic. Essays and reflections were graded by eight design coaches according to a rubric against three learning outcomes. The reflection component was given a separate grade from the essay, though formed part of the final grade for the assignment. Variations in marking between coaches were addressed both through moderation at the start of grading, and then through an examination of the grade distribution for each coach. The graded reflection components form the data for this study. The length of the reflections submitted by students ranged between 162 and 415 words ($M=299$; $SD=44$) with an average of 24 words per sentence. 56 anonymised reflections were randomly selected for analysis following institutional ethics approval. As the chosen reflections were from a version of the course one year prior to the study with student scores finalised, students were free to choose to not have their

reflections included in the study. One of the authors of this work anonymised the student reflections while another author analysed and coded the anonymised reflections. The author who anonymised the reflections also contacted the corresponding students to give them the option to opt out of the study.

The passing grades given to the reflection samples ranged from 6 to 10 on a scale of 1–10 with the following general divisions:

- Grade ≥ 9 Excellent (E)
- 9 > grade ≥ 8 Good (G)
- 8 > grade ≥ 7 Moderate (M)
- 7 > grade ≥ 6 Poor (P)
- 6 > grade ≥ 0 Very poor (VP).

Along with the text of reflection, metadata included: the subsequent grade, the coach who graded each reflection, and the coach's comments.

4.2 Analysis

As described above, Ullmann's (2019) model of reflection detection was used as the guiding framework for this study. The eight reflection components of the model – experience, difficulty, belief, feeling, perspective, learning, intention, and description – providing an initial coding scheme for the reflective texts.

We adopted an exploratory data analysis methodology (Tukey, 1977) to gain deeper insights into the reflective writings of design students. The initial phase involved qualitative coding of 56 reflective texts by one researcher. Coded examples corresponding to the components of reflection are presented in Table 1. Subsequently, the frequency of occurrence for each reflection component was extracted, providing quantitative insights into their frequency.

Following the coding of the data, we conducted a dictionary-based linguistic analysis of the reflection text using Linguistic Inquiry and Word Count (LIWC) (Boyd et al., 2022) to look at their linguistic elements. The latest version of LIWC (2022) uses around 120 predefined and validated dictionaries or word categories (referred to as LIWC categories) relating both to linguistic function (e.g., pronoun, adverb) and psychosocial categories (e.g., cognitive processes, affective processes) to examine linguistic patterns and word usage for the reflective texts. The benefit of LIWC is that it can be applied consistently across many examples of text, thus addressing the limitations of scale faced in manual coding.

To investigate the linguistic characteristics of each reflection component, we conducted a general LIWC analysis for each reflective text. This allowed a relationship to be drawn between LIWC categories and a particular reflective component. The illustrated example below shows how we did this for the 'Difficulty' component. This approach was similarly applied to the remaining seven components, allowing us to understand the linguistic markers related to each component.

Table 1 Coded examples of student reflections using Ullman’s eight components of reflection.

Component of reflection	Examples
Experience	“During my minor Education I had to write down a lot of my reflection on paper so you will not forget the recommendations that you wrote to yourself.” [ID 8]
Belief	“If we do not have design options to analyse and reflect on, how can we be expected to conduct this at a faster and more efficient rate in industry where deadlines are strict?” [ID 11]
Difficulty	“Even though my design process has been close to the co-evolution model, I have been fixated on the conception that design is about rational problem solving so its process should also follow rational steps of analyzing and synthesizing.” [ID 5]
Perspective	“I do notice, like Nordby & Schønheyder tell in their paper, that it is very useful to tweak the design methods a little bit to your own design problem.” [ID 24]
Feeling	“This was very refreshing as this was something I often unconsciously did as a designer, but would get frustrated at not finding the right solution.” [ID 9]
Learning	“Writing the essay helped me realise that personal leans and a particular uncommon way of framing the problems, which is an imprint of a lived experience, is a strong factor in building expertise.” [ID 16]
Intention	“I hope that in my next design practice, in the stage of analyzing problems, I will take myself as an observation sample, introduce the design vision and observe what it brings to me.” [ID 48]
Descriptive	“Design visions should be a way of expressing your personality through design and to create unique solutions.” [ID 44]

The 'Difficulty' component in the reflection model represents an exploration and evaluation of challenges faced. It also provides insight into deeper introspection, addressing personal, academic, or professional difficulties, and revealing a capacity to learn and grow from complex experiences.

The component of ‘Difficulty’ in the context of LIWC categories represents discussion and critical assessment of challenges, obstacles, or struggles evident in the text of reflections. It is characterized by the presence of linguistic features such as the use of impersonal pronouns (‘ipron’: e.g. it, that, this, what, itself, etc.), auxiliary verbs (‘auxverb’: e.g. is, was, be, can, have, etc.), negations (‘negate’: e.g. not, never, none, no, etc.), a focus on present-related words (‘focuspresent’: e.g. is, are, can, currently, etc.), causation-related words (‘cause’: e.g. because, how, used, etc.), and differentiation-related words (‘differ’: e.g. or, but, not, which, etc.). The presence of these linguistic markers in the text thus helps identify passages that include ‘Difficulty’. In Table 2, two sentences that were coded as Difficulty can be seen, along with the highlighted LIWC categories as identified.

Table 2 Examples of sentences manually coded as 'Difficulty' with highlighted words representing the LIWC categories co-occurring more frequently with the 'Difficulty' component.

LIWC Category
<i>ipron</i> <i>auxverb</i> <u>negate</u> <i>focuspresent</i> <i>cause</i> <i>differ</i>
I wanted to create a product that brought nature into the home in a way that increases happiness and serenity, but <u>didn't have</u> a clear enough idea of what people appreciate about nature and how they interact with it.
This experience has caused me to take more time at the beginning of a project to analyse the case and formulate a goal, but to also be open to a change in perspective or direction with new insights and input as I get further into the project. [ID 17]

From the frequency of occurrence of 'difficulty' in each reflection text and the LIWC analysis scores, we produced scatter plots (see Figure 1 for an example) to re-assess the coding and identify trends and outliers using the LIWC 'case studies' feature, which allows a user to highlight selected LIWC categories in the context of the surrounding text. The purpose was to visually understand the relationships between LIWC categories and the 'Difficulty' component, identifying trends, outliers, and potential associations.

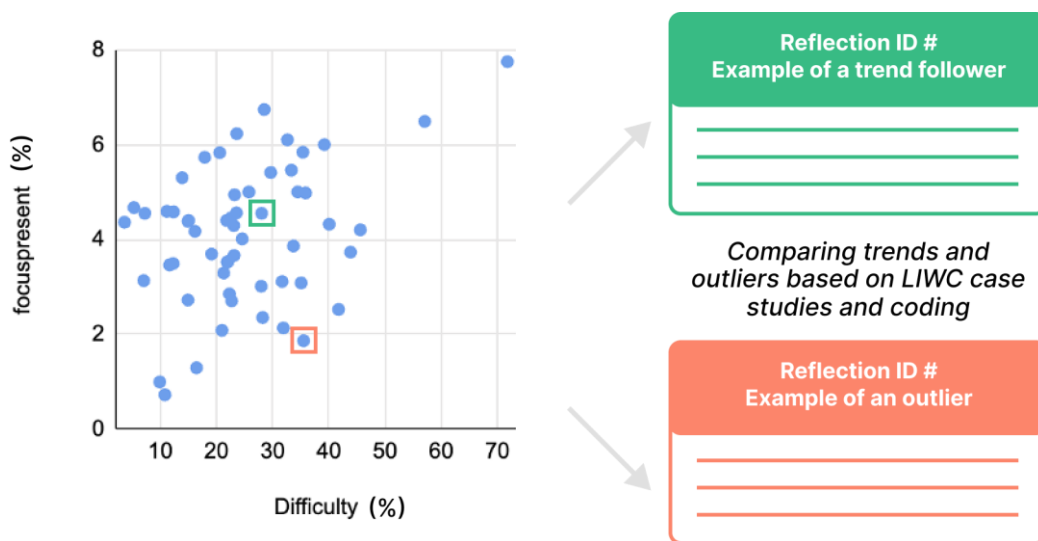


Figure 1 A snapshot of the explorative data analysis process of visually examining student reflections coded for a particular category from Ullman (2019) and LIWC dictionary categories. Each point on the scatterplot on the left represents a student's reflective text. The x-position of the point corresponds to the percentage of sentences in that text coded as 'Difficulty', normalising for sentence length. The y-position of the point corresponds to the score assigned to that text under the LIWC dictionary category of 'focuspresent' (percentage of words in the reflective text that are also included in the dictionary category). A visual examination of the spread of student reflections shows a general trend indicating that reflective text that discusses 'Difficulty' may also use text that indicates a focus on the present. Reflections that appear to follow this trend (point marked in green) and those that do not (point marked in orange) are both examined closely in the context of the surrounding

text to establish whether an association exists. LIWC categories that seem more associated with the reflection components through this process are shown in Figure 4.

In the final phase of the analysis, we looked at the reflection components and linguistic markers that constitute a high-quality reflection. Patterns and relationships between the assigned grade ranges and the components of reflection were looked at to identify consistent trends associated with higher-graded reflections. Additionally, a comparative analysis was conducted, encompassing the grade ranges, the reflection components, and the LIWC categories linked to each component. This comparative exploration aimed to pinpoint the specific reflection components or combinations thereof, along with associated linguistic features, that contributed to higher-graded reflections. Figure 2 shows an example of a text that was graded ‘excellent’ along with the way in which it was coded according to Ullman’s reflection components.

My experience of the design process and what I expect from myself have changed. As previously, I have been aiming for an Evidence-Based Decision- Making model of the design process; after understanding the role of abstract patterns within the design process, I aim to trust my intuition more and don't rationalize every next gambit with factual evidence. Therefore I aim my design process to follow the model of Directed creative exploration (Adams et al, 2011). In order to achieve that adaptability of the design process and master reflection- in-action, I realize I still lack my experience in design (3 years) and the library of schemata and gambits to be more confident in my design process.

I also have made a particular observation on my previous experience within the law (8 years), that the type of abstract thinking used within the law to create a schematic model of a particular relationship is helping me to “see” the structure. However, I still am de learning the analytical way of approaching the problems. Writing the essay helped me realize that personal leans and a particular uncommon way of framing the problems, which is an imprint of a lived experience, is a strong factor in building expertise. Resolving my ontological “why” and serving a greater purpose for the benefit of society was motivating me to explore the unknown “frames” and take risks within my project. That I will continue to embrace, understanding that brings me confidence and reinforces my confidence to negotiate my way of seeing within the professional environment. Also, I will include drawing a schematic representation of my design process in every project, not only as a means to communicate the work to the client but as a reflection and learning point for my expertise development.

Experience	
Experience	
Difficulty	Perspective
Learning	
Learning	
Difficulty	
Learning	
Experience	
Intention	Feeling
Intention	
Difficulty	

Figure 2 Example of a reflection graded as ‘excellent’ (ID 16: Grade 10). The student effectively intertwines personal experiences, critical analysis, and learning moments, contributing to the reflection’s coherence and depth. Note that reflection components are color-coded, and sentences with overlapping components are underlined to distinguish the other component.

5. Results

5.1 Reflection components

Figure 3 shows that reflective texts used personal experience, expressions of learning and future intentions, and personal beliefs and perspectives. The component ‘Difficulty’ was

most prevalent, being present in all reflection samples. This indicates that students frequently analysed challenges, obstacles, or struggles they encountered in their practice. The components of 'Experience', 'Intention', 'Belief', and 'Learning' were also prevalent, present in 89%, 89%, 84%, and 80% of the reflection samples respectively. The components of 'Feeling', 'Descriptive', and 'Perspective' were also present, albeit to a lesser extent.

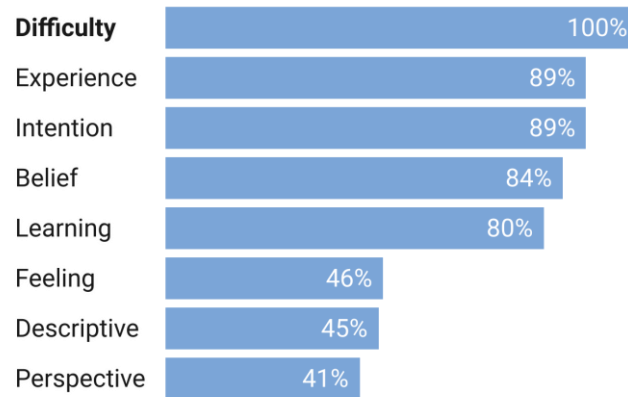


Figure 3 Percentage of student reflections that incorporated the specific reflection components. Notably, 'Difficulty' is consistently found in all samples, indicating a recurrent analysis of challenges, while other components such as 'Experience', 'Intention', 'Belief', and 'Learning' were also prevalent, underlining the significance of personal experiences, intentions, beliefs, and learning within the reflective content.

5.2 LIWC categories in relation to reflection components

Figure 4 shows an overview of the LIWC categories in relation to reflection components that we identified through the process described in Figure 1. It is important to acknowledge that not all reflection components can be uniquely identified by the presence of specific LIWC categories. There are certain linguistic elements that are shared between the reflection components (see Figure 4), which at least partly may be due to the LIWC categories themselves sharing words between them (Boyd et al., 2022).

Figure 4 shows that within the linguistic function category, the use of first-person singular pronouns ('I') exhibited a weak relation with multiple reflection components, including 'Experience', 'Belief', 'Feeling', 'Learning', and 'Intention'. This suggests that students tend to express their personal experiences, beliefs, feelings, learning processes, and intentions using first-person language. On the other hand, the presence of third-person singular pronouns ('she/he') and third-person plural pronouns ('they') showed relatively weak relations with the 'Perspective' and 'Descriptive' components, indicating that their presence alone may not strongly differentiate specific reflection components.

Impersonal pronouns, such as 'that,' 'it,' 'this,' or 'what,' demonstrated a weak relation with the 'Belief' and 'Difficulty' components. The use of these pronouns may indicate a focus on abstract ideas or concepts rather than personal experiences within reflective writing. Similarly, the presence of auxiliary verbs like 'is,' 'was,' 'be,' or 'have' showed a weak connection with the components of 'Belief' and 'Difficulty'. This suggests that students may

employ these verbs to express their beliefs, perspectives, or critical assessment of challenges and struggles encountered in their reflections. Negations, such as ‘not,’ ‘no,’ ‘never,’ or ‘nothing,’ exhibited a relation with the ‘Difficulty’ component. The presence of negations may suggest a critical analysis of challenges and obstacles experienced by the student. However, it is important to consider other linguistic features and contextual cues to accurately distinguish the ‘Difficulty’ component from other reflective domains.

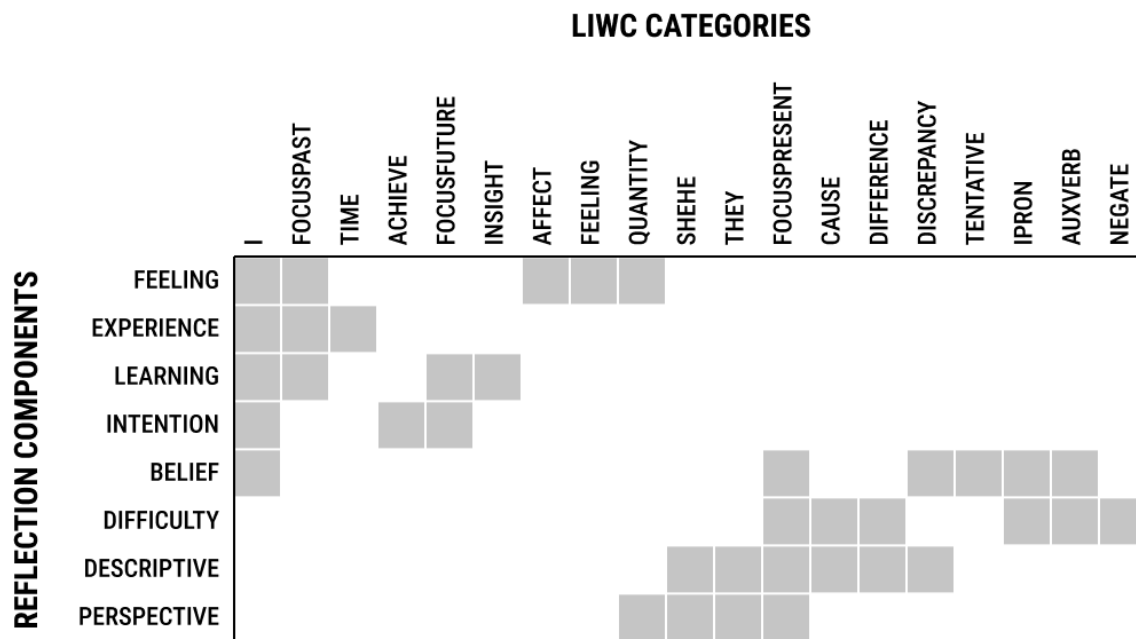


Figure 4 Shared linguistic features in reflection components: This matrix reveals how various reflection components (rows) align with certain LIWC categories (columns). For instance, the prevalent use of first-person singular pronouns (‘I’) is linked to multiple reflection aspects, including Experience, Belief, Feeling, Learning, and Intention. These connections show the relationship between word categories and the components of reflective writing.

In the ‘cognitive processes’ category (part of ‘psychological processes’ in Figure 4), words associated with ‘insight’, ‘causation’, ‘discrepancy’, ‘tentative’, and ‘differentiation’ showed some relations with various reflection components. These linguistic features indicated cognitive engagement in terms of gaining new knowledge, understanding underlying factors, considering alternative viewpoints, expressing tentative thoughts, and analysing distinctions within reflections. Insights, represented by words like ‘know,’ ‘how,’ ‘think,’ or ‘feel,’ are associated with the ‘Learning’ component, indicating students’ engagement in reflective practices to gain new knowledge, and understanding. The ‘cause’ words, such as ‘because’ and ‘why,’ are associated with ‘Difficulty’ and ‘Descriptive’ components, reflecting students’ reflection on underlying factors and influences. Differentiation-related words, like ‘but’ and ‘not,’ indicate cognitive analysis of distinctions and alternatives within reflections, while discrepancy-related words, such as ‘would’ and ‘could,’ highlight consideration of alternative

viewpoints and possibilities. The presence of these linguistic elements enriched the cognitive dimension of reflective writing.

The time-related words exhibited weak to moderate relations with the 'Experience' component. The inclusion of temporal markers allowed students to reflect on specific temporal aspects or recount past experiences within their reflections. Additionally, a temporal emphasis on previous events, emotions, or acquired knowledge was observed through the focus on past-related words. The focus on present-related words demonstrated a weak relationship with multiple categories, suggesting an emphasis on current experiences, beliefs, challenges, perspectives, emotions, or descriptive accounts. Furthermore, the focus on future-related words showed a strong relationship with the 'Intention' component, indicating individuals' articulation of their intentions, plans, or goals for future actions or behaviours.

Finally, other LIWC categories, such as achievement-related and affect-related words in the 'psychological processes' category displayed weak relationships with specific reflection components. These linguistic elements captured the motivational and goal-oriented focus of reflections, as well as the expression of emotions and affective states within reflective writing. There are overlaps and shared linguistic features among reflection components, requiring consideration of multiple cues for accurate categorization. Additionally, similarities in linguistic patterns between certain components, such as 'Descriptive' and 'Perspective', were observed, indicating potential overlaps or shared characteristics. Therefore, a comprehensive analysis incorporating multiple linguistic features and contextual information is necessary for precise identification and interpretation of reflection components.

5.3 Correlation of LIWC categories and grades

Figure 5 shows the distribution of the 56 student reflections across the grade ranges described in Sec. 4.1.

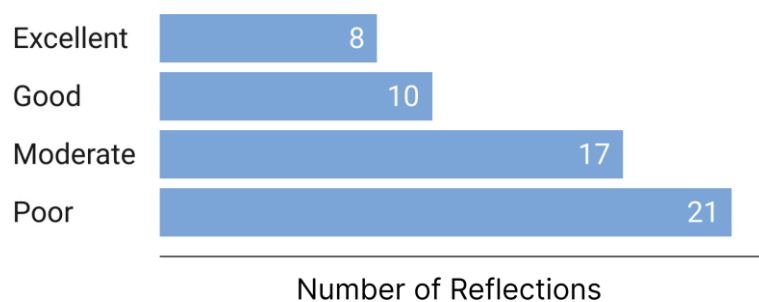


Figure 5 Distribution of reflection samples across grade ranges. Most samples fall within the 'Moderate' and 'Poor' categories, with 'Excellent' and 'Good' samples constituting smaller portions of the dataset.

While analysing the individual reflection components across the grade ranges, a few notable patterns were observed for the 'Perspective' and 'Feelings' reflection components.

Reflections graded as 'Excellent' generally featured a higher occurrence of 'Perspective' (see Figure 6 left), but exceptions were found where reflections emphasized outcomes instead. While some reflections in the grade range of 'Poor' lacked perspective, those that did incorporate it, did so without effectively linking theories covered in the students' main essays to personal experiences. We should thus be careful not to infer that mentioning perspective is sufficient to qualify a reflection as being of good quality; other rubrics may come into play when it comes to grading. In this case, that rubric included integration with essay themes and concepts. The trend is reversed for the component of 'Feeling' component, with 'Excellent' and 'Good' grades showing fewer explicit mentions of feelings (see Figure 6 right). In contrast, 'Moderate' and 'Poor' grades exhibit higher occurrences, but just as we found for 'Perspective', the precise role of the reflection component in predicting reflection quality requires a deeper analysis.

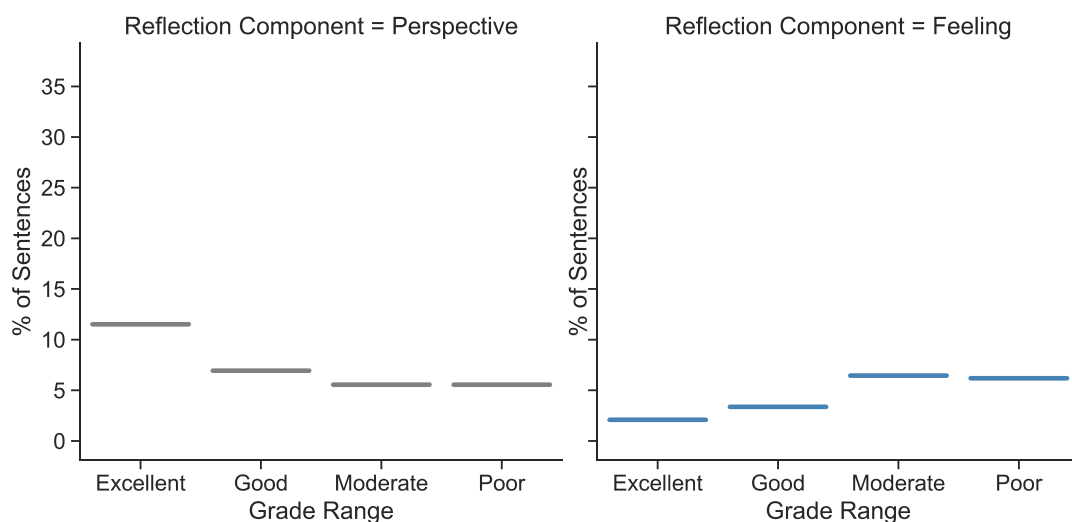


Figure 6 Means and distributions of reflection components of 'Perspective' and 'Feeling' across grade ranges show some patterns. Horizontal bars show mean values and points represent individual reflections. The plot on the left in grey shows the percentage of sentences for each reflection (compensating for sentence length using word count) that are coded with the reflection component of 'Perspective'. While there is variation across individual cases, reflections graded as 'Excellent' generally appear to incorporate more perspective, whereas reflections graded as 'Poor' in general appear to feature fewer sentences incorporating perspective. The plot on the right in blue shows a similar measure for the reflection component of 'Feelings'. Reflections graded 'Excellent' and 'Good' appear to contain fewer explicit mentions of feelings, while those graded 'Moderate' and 'Poor' appear to exhibit a higher occurrence on average.

5.4 Holistic narrators and in-depth explorers

No notable patterns or trends were observed in the distribution of occurrence for the categories 'Experience', 'Difficulty', 'Learning', 'Intention', and 'Descriptive' across different grade ranges. The occurrence of these categories alone did not consistently differentiate higher and lower grades. However, it is important to note that combinations of certain categories might play a role in higher grades for a reflection. We analysed the reflections

graded 'Excellent' for such combinations, which revealed two distinct types of reflections, each contributing to higher grades but with different emphases and characteristics.

The first type, seen in five out of the eight reflections graded 'Excellent' display characteristics such that we label them as written by '*Holistic Narrators*'. These reflections emphasised personal experiences, learning, intention, and positive outcomes. These reflections showed high occurrences of the components of 'Experience', 'Learning', 'Intention', and 'Outcome'. This suggests that when students integrated their experiences into their reflections and demonstrated meaningful learning and intention derived from those experiences, it led to higher grades. Holistic narrators displayed the ability to describe multiple experiences, provide a brief yet critical assessment, incorporate beliefs and other perspectives, and articulate multiple clear intentions and specific lessons learned.

We labelled the remaining three of the eight reflections graded 'Excellent' as written by '*In-depth Explorers*'. These reflections focused more on critical assessment, multiple perspectives, and featured descriptive text. They showed high occurrences of the components of 'Difficulty', 'Perspective', and 'Descriptive'. This indicates that when students engaged in critical assessment, considered various perspectives, and provided descriptive explanations, it contributed to a higher emphasis on the challenges and complexities encountered in their design practice. While these reflections showed fewer occurrences of the components of 'Learning', 'Intention', and 'Outcomes', they excelled in evaluating the design process from diverse perspectives, resulting in higher grades based on their ability to critically analyse and articulate different viewpoints. The in-depth explorers demonstrated characteristics such as a focus on a few experiences, in-depth critical assessment, consideration of multiple perspectives, and fewer specific intentions or lessons learned.

Reflections that scored lower appeared to do so due to several factors: they lacked the incorporation of multiple perspectives and exhibited an imbalance in addressing categories like experience, learning, and intention. Additionally, a disconnect between beliefs and personal experiences appear to have contributed to their overall lower quality compared to those with higher grades.

Specific LIWC categories revealed associations with reflection quality. The 'achieve' category positively aligned with higher grades, suggesting that using intention-driven language corresponded with better grades. Conversely, an overemphasis on emotions, as indicated by the 'feeling' category, showed a negative association with grades. Nevertheless, relying solely on LIWC analysis has limitations. Grading involves multidimensional factors not fully captured by LIWC, including critical thinking and coherence. Furthermore, the relationships between LIWC categories and reflection components are not always straightforward and overlapping dictionaries complicate interpretation. For a comprehensive assessment, it is crucial to combine LIWC insights with expert judgment, examiner feedback, and a defined rubric when evaluating reflections.

6. Discussion

The analysis of LIWC categories in relation to reflection components revealed linguistic patterns associated with various reflection components, though the correlation needs closer examination. Some linguistic categories are shared among reflection components, showing the nuanced and complex nature of reflective expression. Based on an examination of the reflection components within the reflective writing graded 'Excellent', two distinct types of reflective writers were revealed — *holistic narrators* and *in-depth explorers*. Holistic narrators emphasised personal experiences, learning, intention, and positive outcomes, while in-depth explorers emphasised critical assessment, multiple perspectives, and descriptive narratives. These findings underscore the richness and diversity of reflective writing, emphasizing that a single approach doesn't fit all.

A detailed examination of the linguistic elements of reflections offers valuable implications for designers, design educators, and researchers. For educators, this study lays the groundwork for evidence-based guidance in teaching reflective writing. It provides a basis for effective communication of assessment rubrics, facilitating clearer expectations for students. Furthermore, educators can utilize this understanding to offer targeted feedback, guiding students on how to improve their reflective writing style. By identifying linguistic patterns associated with higher grades, educators can offer targeted strategies for students, including enhancing critical analysis, balancing personal experiences with theoretical perspectives, and improving clarity and coherence. The two primary types of effective reflections that we have identified could guide design students and practitioners in consciously choosing an appropriate approach based on the context. Potentially, this offers a structured framework for improving written reflections, fostering a deeper awareness of the linguistic features of writing, and facilitating self-improvement. Understanding linguistic features of written reflections enhances students' design process and production by providing a structured framework for self-awareness, critical analysis, and effective communication, aligning with Bolton's (2010) perspective on reflective writing as a form of professional development. For researchers, we have shown the promise of developing dictionary approaches for evaluating reflection, informed by manual coding. The approach needs further refinement, but the initial results point to an approach that could scale well for higher numbers of reflective text, potentially leading the way to augment manual assessment with automated approaches.

The insights reported in this paper facilitate student support and feedback, enabling educators to offer personalized guidance, deepen critical thinking, and foster self-reflection. Integrating quantitative linguistic analysis with qualitative methods can provide a comprehensive view of reflective writing, considering both structural aspects and subjective experiences. Longitudinal studies tracking reflective writing development can inform interventions and curriculum enhancements. Exploring additional linguistic features, such as syntactic structures and rhetorical devices, can further illuminate the relationship between language and reflection. This research empowers design students to enhance their communication skills along with personal and professional growth as reflective practitioners.

7. Limitations and future work

While a LIWC analysis offers valuable insights into the linguistic aspects of reflections and their potential correlation with grades, it is essential to recognize the inherent limitations of this approach. Subjectivity in the coding process, word-level analysis versus sentence-level coding, and the overlap of LIWC categories highlight several areas for development. Though LIWC provides stable and validated dictionaries, the complexity and ambiguity of reflective (and designing) language poses additional challenges that are long recognised for dictionary approaches: polysemy, irony, (double) negation, and other cases where the interpretation depends on sentence parsing and contextual cues. In addressing these limitations, a more comprehensive approach that integrates qualitative methods and supplementary predictors can enhance the precision of grade prediction models. Additionally, ethical concerns regarding automated grading systems underline the need for balance between automation and human oversight to ensure fair and unbiased evaluations (Wang et al., 2023). However, our approach could be incorporated into human-in-the-loop approaches of text analysis where the nuance and domain knowledge of a researcher or practitioner is augmented—but not replaced—by the scalability and power of automated approaches.

It is crucial to note that the course is primarily theoretical, and the grading of reflections is independent of any actual design work. Thus, this study does not examine whether high-scoring reflections about the students' design process translate into better design processes or outcomes, an aspect outside the scope of this research.

Finally, the analysis does not account for differences in English proficiency among students as a factor influencing the kind or quality of the reflection. While the university's English-language requirements for admission would potentially minimize these differences, the "quality" of the reflection—or at least its score—may still be affected by the student's language proficiency. These are aspects to consider for further extensions of this work.

8. Conclusion

Reflective writing is a crucial skill for designers, as it enables them to critically analyse their experiences, enhance their learning, and foster professional growth. Looking at reflective writing and exploring the relationships between linguistic features and the quality of reflections, this research sought to contribute to a deeper understanding of how design students engage in reflective practice and provide insights for educational approaches and interventions. Our study draws upon an in-depth analysis of 56 reflections using LIWC and the model of reflection proposed by Ullmann (2019). We identified two distinctive reflection types: *holistic narrators*, who emphasised personal experiences, and *in-depth explorers*, focused on critical self-evaluation. These findings have implications for the field of design education, offering educators valuable insights to tailor interventions that promote critical thinking and diverse perspectives among students. Furthermore, they provide a solid basis for the development of automated tools and natural language processing techniques, empowering educators to assess and enhance reflective practices. In showing the

multifaceted nature of reflective writing, this research holds potential for contributing to design education, equipping both educators and students with the knowledge and tools needed to foster effective self-reflection and growth.

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