Analyzing Engineers Writing for Non-engineers

***Abstract*— Engineers spend a considerable amount of time in communicating with technical and non-technical audiences when on work. Due to the high demands of good technical writing skills, special measures are taken by most engineering faculties and engineering educators for fostering such attributes but writing skills for non-technical people is often overlooked. A vast majority of students stumble into writing with an inadequate sense of the importance of their audience — a problem that needs attention. This introductory study analyzes the engineering students' writing when addressing non-technical people. We conducted short writing exercises in a third-year engineering course aiming at pitching an idea to non-technical audiences with a view to assessing their ability to adapt their writing according to the audiences. These writings are analyzed using the freely available text analyzing tools. The analysis revealed that students' writings are complex and tend to address the more qualified people than general audiences. Furthermore, their writings are usually dominated by an analytical tone. The initial findings provide enough encouragement to further explore this topic and provide a basis for related practitioners to address this issue and develop strategies to overcome this issue.**

Keywords—writing analysis, engineering education, writing tone, communication skills, and teaching/learning strategies.

I. INTRODUCTION

The demand of engineers is continuously growing since the middle of the second century due to rapid developments in science and technology. Writing is an essential soft skill for every aspiring engineer as most of the companies are owned by rich investors who find it hard to communicate technical information in a way that is easily understood by their audiences. This is as important as developing a product and hold value to both engineers and their companies. Therefore, engineers need to possess good communication skills which allows them to transmit information effectively and adds tremendous value to their career. The impressive work produced by engineers is useless unless it is communicated to others in a way that they understand. Poor communication is said to be the reason behind some of the most catastrophic engineering failures such as the Space Shuttle Challenger disaster (1986) and the loss of the NASA Mars Climate Orbiter (1999).

Communication skills are important attributes for today's engineering graduates [1] which is one of the key outcomes required by an undergraduate engineering programme under the ABET Engineering Criteria 2000 [2] and Washington Accord accreditation standards for Engineers [3]. These accreditations demand that engineering programs must assess students' technical skills but also professional skills such as effective oral and written communication.

Engineers usually work on large and complex projects which require integration of many groups spread across the component of design as well as the customers and suppliers. Each group comprises engineers with diverse skills carrying out different activities. A study of a single cohort of university engineering graduates providing detailed information on the early career of Australian engineering graduates discloses that about 60% of the time at work is consumed on communications with other people either face to face, on the telephone, or through written documents [4]. More precisely, engineers across all disciplines, spend more than 25% of their time in writing documents. Engineers in manufacturing industry of Australian were found spending over 70% of their time on documentation-related activity [5]. There are many research studies that have reached similar conclusions with the total reported time on direct communication activity ranging from 45% to 75% [6, 7].

Engineers do a lot more writing than what is assumed by the rest of the world. Efforts of an engineer are not complete until the documentation outweighs the final product. Good writing skills bring a lot of benefits to engineers. It improves their prospects of landing a job as good writing skills help in creating a compelling cover letter and writing style is one of the key factors that influence the decision of hiring experts [1]. Good writing skills also allow them to promote themselves through presenting their work and achievements to the people all over the world through blogging aiming for a broad audience that requires communicating in a manner that is easy to understand. It makes it easier to communicate ideas and business case with the management and writing the contents in a compelling fashion convinces them and consequently, secure the job. It also helps engineer creating various documents at the workplace which include technical documentation, specifications, system requirements, manuals, warranty restrictions, and other parts of the product documentation intended for third-party individuals, users, or technical support. Writing skills also help in communicating with different divisions in the company as they work with various departments in the company such as sales, marketing, and other divisions that are not inhabited by engineers and technical staff. Much of the internal communication goes via emails and good writing skills allow you to create clear emails that are easy to understand, which makes the job easier for other members of the company. Lack of written communication skills at the workplace can also have negative effects on stress levels, deadlines, morale, and health, which in turn can lead to misinterpretations adversely affecting the problem resolution capability resulting in time wastage and inefficiency at work [8].

Engineers often find it hard to express themselves concisely and logically by writing English text as most of the time they work with mathematical derivations, equations, and programming. As a result, students get proficiency in writing mathematically consistent equations and expression where the

logic is embedded in the language itself but in real-world logic has to be explained using the words. Writing concisely and logically about the real-world concepts in English is an entirely different skill which is difficult to master and engineers are no better than the majority of other people [9]. They feel challenged when it comes to the words and often find themselves disadvantaged when they present the logical arguments to the decision-makers who are often good at words [10]. Many engineers need to master the ability to reason concisely and logically using the language their audience can understand. Furthermore, engineers produce many kinds of writing during their academic as well as professional writing which includes: notes during class sessions, lab reports, written assignments, term papers, e-mails, presentations, memos, proposals, and messages for which students have a clear writing objective and audience [11].

Therefore, academician should help students to learn the specialized register of the engineering profession which will help them to become successful professional. This also increases access to the information and also the ability to participate in varying communities. This is an important skill that needs attention for smoothing the critical transition phase of students from undergraduate education to either the workforce or graduate school. Undergraduate level engineering courses do not really target to develop this capacity in the students.

Furthermore, engineers need to speak to the rest of the world using different methods such as emails, websites, advertisements, reports, budget requests, proposals, pitches, websites, manuals, FAQs, etc. In order to do it effectively, they should be able to convince the customers otherwise they will mystify customers and end-users alike. The inability to write for a non-technical audience can dramatically limit the audience. The whole point is to make everything clear for your client. Therefore, when writing, it is important to keep audiences in mind as they are persons who actually be reading your document, or receiving your emails. Engineers usually make the mistake of ignoring the audience. They have to write different documents which are read by the different audiences. Therefore, it is essential to keep audience top of mind as it will change the way of writing the document. A good document is the result of a complex process that factors in readers and their knowledge. In industry, engineers are required to write for a large, diverse audience all with different informational needs and expectations for a report. Sometimes the complexity of your idea could not be read by non-technical personnel without proper wording that is easy to understand. They are likely to be much less familiar with the technical details and they may act on, or be affected by, the report. The student's ability to explain the concepts in an easily understandable language is also an indication of the fact that he has a good grasp of the subject. If a student is unable to explain a complex technical concept in non-technical terms, his understanding of the technical concepts may be questioned. Also, the business cases are presented to the people who do not have much technical background and it is important to communicate the benefits of the proposed project or idea to the management in an effective way which is easy to understand.

This small-scale study reported here contributes to our engineering communication awareness by providing information about engineering students' ability to write while keeping in view the audiences. It was motivated by the research questions: Do undergraduate students have the ability to write for non-technical audiences? In other words, can they adapt the tone of their writing according to the audiences?

II. THEORETICAL FRAMEWORK

There is a trend of incorporating more and more writing exercises to support a wider variety of learning outcomes. Writing exercises are used to achieve a deeper level of understanding, enhance students' critical thinking skills, to identify learning bottlenecks and misconceptions, and assess and evaluate student learning and understanding in ways that cannot be tested with simple calculation-based questions [12]. These engineering classroom activities are closely aligned with the broader Writing Across the Curriculum (WAC) movements [13] according to which writing is the responsibility of the entire academic community. Also, writing instruction must be continued during all four years of undergraduate education as it promotes learning. Writing assignments are designed to support the goals of Writing in the Disciplines (WID) as it is aimed to gain familiarity with genres and it is used by a large number of WAC programs, although not precisely as our writing pieces are very short. The writing assignment is combined with Writing to Engage (WTE) as it allows students to practice critical thinking as well as engages them in critical thinking.

A. Discourse Theory

The language can be divided into different levels such as Phonology, morphology, semantics, syntax, and discourse [14]. Discourse can be defined in different ways such as a conversation or text, collection of texts or conversations, a shared way of talking or creating texts (code), codes, languages, and ways of speaking of a topic. According to Cambridge Delta, any connected piece of speaking or writing is referred to as discourse. Discourse Analysis is the study of how the separate 'bits' of language which make up the discourse are connected in such a way that the discourse makes sense. In case, if it doesn't make sense, discourse analysis enables us to find out why [14].

B. Readability and readability Test

According to Wikipedia, Readability is the ease with which a reader can understand a written text. Easy reading helps learning and enjoyment, so what we write should be easy to understand. In natural language, the readability of text depends on its content and its presentation [15]. Readability tests are formulae used to evaluate the readability of a text. There are many (more than 17) significant measurable style variables used to measure the readability of the text and most commonly involves counting syllables, words, and sentences. Readability tests are often used as an alternative to conducting an actual statistical survey of human readers of the subject text (a readability survey). A list of the readability tests is provided in Table I.

Writing is analyzed using freely available online text content and readability analyser tool called *Analyze My Writing*. The output of the tools is readability index which is an estimation of how difficult a text is to read which is based on the text's complexity. There are many indexes available for indicating the complexity of the writing which differ in their working and each emphasizes particular aspects of text complexity. Some emphasize syllable counts while others look only at the word and sentence lengths. But, all are based on the same core idea; readability is essentially a measure of text complexity. Plung [16] has advocated the application of the readability formulas for the writings (even technical) if they are intended for the general public. A list of available readability tool is given below:

TABLE I. WRITING ANALYSIS TOOLS AND READABILITY TESTS

Writing Analysis Tools	Readability Tests
- *Analyze My Writing* - *Joes web tools* - *ReadablePro* - *The writer's diet* - *Text Content Analysis Tool* - *Hemmingway Editor*	*The Flesch formulas, The Dale–Chall formula, The Gunning fog formula, Fry readability graph, McLaughlin's SMOG formula, The FORCAST formula, The Golub Syntactic Density Score, The George Klare studies, The John Bormuth formulas, The Lexile framework, ATOS readability formula for books, CohMetrix psycholinguistics measurements*

The application of a useful readability test roughly indicates readability of a piece of writing. The tests generate a score based on characteristics such as sentence length (as an unreliable proxy for syntactic complexity) and statistical average word length (which is used as an unreliable proxy for semantic difficulty) of the work. Some readability formulas refer to a list of words graded for difficulty. Many readability formulas measure word length in syllables rather than letters, but only SMOG has a computerized readability program incorporating an accurate syllable counter.

C. Tone analysis

Tone refers to an author's use of words and writing style to convey his or her attitude towards a topic [17]. The author feels about the subject is often defined as the tone which is different from feels is referred to as the mood. The tone should not be confused with a voice which is the author's personality expressed in writing. It is hard for the author to alter his personality but he can adjust his attitude (tone) which can affect the mood of the audiences.

Tone is conveyed through diction (choice and use of words and phrases), viewpoint, syntax (grammar; how you put words and phrases together), and level of formality. It is how someone express oneself in speech or writing. In case of formal writings, the tone is normally clear, concise, confident, and courteous. The writing level should be sophisticated, but not pretentious [17]. A writer's tone is very important, as it conveys a particular message from the writer and affects the reader in a particular way. Consequently, it can also affect how the reader receives the message being communicated. Some of the tones considered in this paper include: *analytical, tentative, confident, sadness, joy or happiness, anger,* and *fear*:

III. WRITING ACTIVITIES

This teaching methodology was incorporated into a third-year of computer systems engineering course in the form of in-class simple writing exercises which had been perceived well by the previous year students [12]. These activities were incorporated in a Digital System Design I course. This course focuses on digital Systems implementation technologies with emphasis on hardware description languages and design abstraction levels; structural, architectural and behavioral modelling; register-transfer level design; datapath and control units; functional and timing simulations; FPGA-based implementation design flow and case studies.

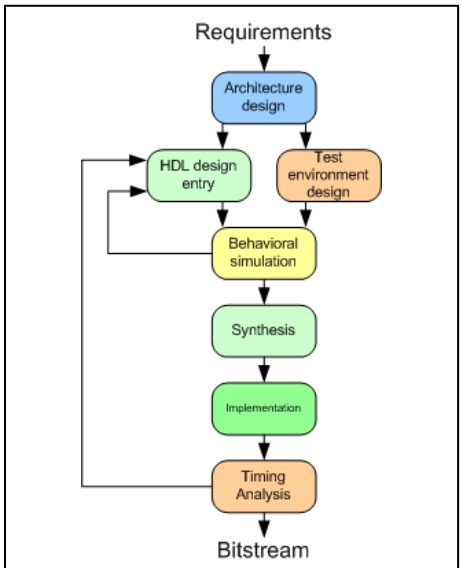

Figure 1: FPGA design flow

Design Flow is a term used to describe the various design phases of an Integrated Circuit (IC) design. The design is usually based on the specification, assuming that they are provided, the most general approach adopted is shown in Figure 1. The informal specification of a digital system are provided by some tender documents which are usually given in a human-readable text or presentation format. These informal specifications are produced by an engineer working in a professional environment. Unfortunately, in the academic environment, students are often provided with the informal specification of a digital system and they never get a chance to go through the two important steps of idea creation and communicating its effectiveness and finally writing down the informal specification of the system. The FPGA design normally starts with the architecture design and steps of problem identification, devising a solution and writing specification are missing. It means they seldom get a chance of going through these important steps of identifying the existing problem to be solved and they only work with the provided specification. The writing exercises are designed to fill the gap identified. Furthermore, the idea for a project comes from inspiration, research, observation, and somebody's comment. Therefore, this activity can help students in developing aforementioned attributes [12].

There were a total of four short writing exercises and only related one is described next. The students were asked to:

"Think of a real-world digital system that could be used to solve an existing problem in the community. You are required to identify the problem, suggest a title for the project, and describe how it may benefit the community. Your description should be between 100 – 200 words, strictly. This activity will be peer-reviewed and marked by at least two other students."

This activity was mainly a practice of pitching an idea for students by answering following simple questions:

- What is it (idea)?
- What might the product/service do?
- What problem might it solve?
- Who will use it?
- What is valuable to the user?

These pieces of writings can be termed as creative writings as they require saying things in words that create illusions or that establish a mood or other desired affects. The students were meant to complete the writing exercises during the lecture time. To ensure equitable access to learning activities and respecting students' time commitments with other engagements, students were allowed to complete the activities after the lecture. As a requirement of the course, it was not compulsory for students to complete the activities but it did carry some very low percentage of marks as a reward for motivating them. The writings were submitted electronically by the submitted which were graded and feedback was provided to students. The feedback was provided using corrective marks and marginal notes. Corrective marks denoted simple word or phrase level errors and marginal notes highlight the specific issues in the writing.

IV. METHODOLOGY

A. Background

The aim of this study is to understand more about engineering's writing style and their ability to adapt the level and tone of the writing according to the audience. An underlying assumption that has informed our thinking about engineering work is that writing is an essential component throughout the career of an engineer. This inquiry examined a third-year engineering course consisting of computer systems engineering students for two consecutive years. The main aim of this research was to assess the students' ability to write for different audiences as well as fill in the gap in the understanding of the Digital System Design course. It is a 15-point medium/advanced course in digital system design intended at Year 3 students of a four-year undergraduate program at the Electrical, Computer, and Software Engineering Department. It builds upon the knowledge and skills acquired in Fundamentals of Computer Engineering; a prerequisite of this course taught in the second-year. The objective of this course is to give the students the theoretical basis and practical skills in the design of medium size modern digital systems using Field Programmable Gate Arrays (FPGAs).

B. Sample

The main data of this study consisted of a total of ~ 79 short pieces of freewriting samples composed by participants in response to the aforementioned activity. The participants were undergraduate students from a large metropolitan university in xxx participated in the study (8 females; 71 males; average age 21 years). All participants were enrolled in a Year 3 Digital System Design I course and received no course credit for participating in the experiment. Participants represented an undergraduate discipline of Electrical, Computer, and Software Engineering. The length of these writing samples ranged between 130 and 350 words.

C. Evaluation

Technical and professional literature found in scholarly journals generally scores above 12. Accordingly, texts which are meant to be accessible to a wide adult audience should fall somewhere between 8 and 12. Advertising copy is written anywhere from a 5th to 8th grade level depending on the market. Writing is analyzed using a freely available online text content and readability analyser tool called *Analyze My Writing* [18]. The output of the tools is readability index which is an estimation of how difficult a text is to read which is based on text's complexity. The attributes of writing which are measure include word lengths, sentence lengths, syllable counts, and so on. There are many indexes available for indicating the complexity of the writing which differ in their working and each emphasizes particular aspects of text complexity. Some emphasize syllable counts while others look only at word and sentence lengths. But, all are based on the same core idea; readability is essentially a measure of text complexity. The tone of the writings was analysed by using freely available tool called *Tone Analyzer* which is capable of analysing 7 different tone as mentioned earlier [19].

D. Measure

Since this was an intervention study, it required the approval of an ethics committee. This study has received ethical approval from the Human Participants Ethics Committee from the University of xxx (Reference No.: xxx). During the first lecture, the principal investigators explained to all students about the writing exercises and addressed their concerns.

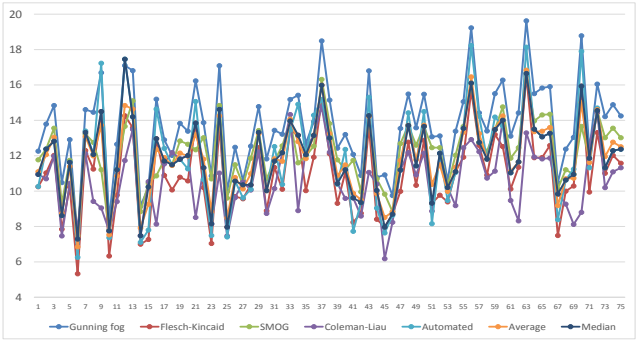

Figure 2: Individual reading levels

V. Results and Discussion

We analyzed all the writings using freely available tool, Analyze my Writing. Readability score reflects the grade level needed to comprehend a passage of text. And the grade level of writing needs should accurately reflect the grade level of target audience. The score for 5 most widely used readability test is shown for individual writings in Figure 2. The score for five readability tests are: *Gunning Fog* (Max.=19.63, Min.=7.29, Mean=13.50, Std. Dev.=2.49) *Flesch-Kincaid* (Max.=16.52, Min.=5.33, Mean=10.90, Std. Dev.=2.31), *SMOG* (Max.=16.65, Min.=7.49, Mean=12.30, Std. Dev.=1.78), *Coleman-Liau* (Max.=14.77, Min=6.18, Mean=10.72, Std. Dev.=1.82), and *Automated* (Max.=18.60, Min.=6.26, Mean=13.50, Std. Dev.=2.79).

The maximum and minimum scores for all five readability test are provided in Figure 3. These score indicate that some of the students are writing at a much higher level than the other. For example, considering the Gunning fog test, the writings span between 7th grader to a person with nineteen years of formal education. The readability score reflects a grade level above or below the grade level of the intended audience, and text need re-work to better resonate with intended target.

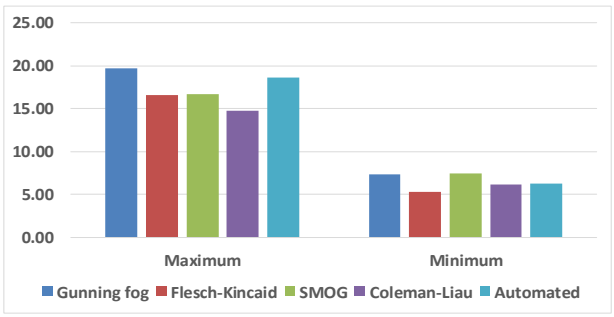

Figure 3: Maximum and minimum levels reading levels

The average for each test and overall average of for all writings are given in Figure 3. The results indicate that on average, students writing target the audience between grade 11 and 14. American adult reads at a 7th to 9th - grade level. In order to maximize readership, it is important to keep content within that range. These finding are shared with the students who can take measure to reduce/increasse the complexity of

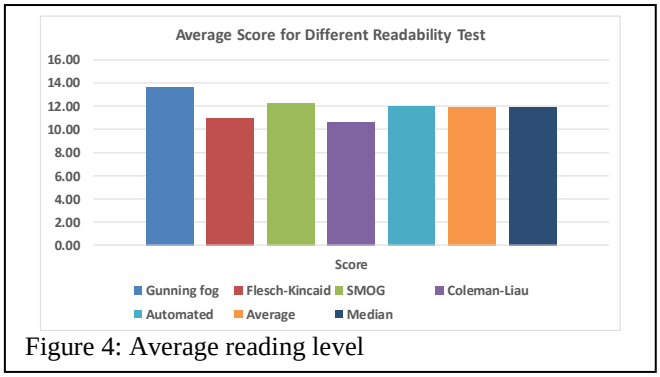

Figure 4: Average reading level

the writing and make it more engaging for the readers. We intend to include a follow up writing in future so that students could see the analysis of their writing by using the tool and resubmit their writing after bringing down or raising the complexity to the required level.

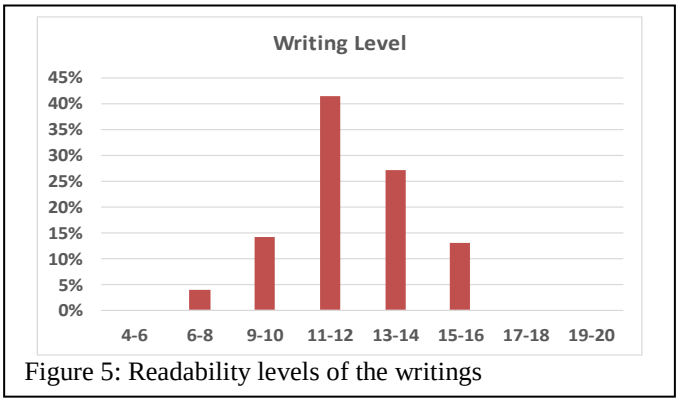

Figure 5: Readability levels of the writings

Around 14% students' writing were in suitable range for the audiences and 4% writing were too easy. Around 82% of the students' writing were not suitable for targeted audiences. This is in accordance with Winsor finding that engineering students do not think that they are arguing for an interpretation or convincing an audience when they write but believe instead that they are conveying data or describing reality. This can be improved by providing useful feedback otherwise they will have to learn on job by interacting with real audiences. In this way, the students become more and more aware of audience and tune their writing to suit them based on the feedback provided by them. This problem can be fixed during their stay at university so that they are productive when they start their professional career. It will also save the precious resources of the organization spent on training them.

We analyzed the tone of all 79 writings and result are shown in Figure 6. Majority of the writings have *analytical* tone which was expected as these writings contain the reasons or logic/ justifications to support the idea presented. This also indicates that students analyzed an issue, presented the pros, and compared two scenarios (situation before and after suggested solution) and indicated why presented idea is better etc. This is required from the engineering students that they discard the colloquial write and embrace a more professional,

analytical tone. It is preferred that they use precise language, sound confident, avoid unfamiliar language, prioritizing clarity, and get rid of filler words [20].

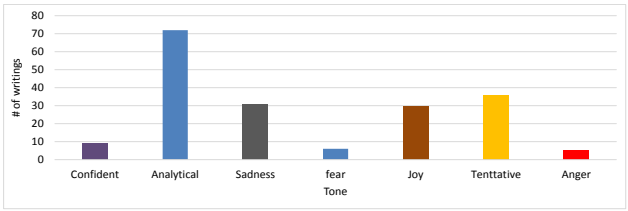

Figure 6: Number of tones in writing

Around ~36 writing pieces had a *tentative* tone that can be attributed to students' cautious approach when making their claims as these claims are not proven or established beyond doubt or debate. There were 8 writings that had *confident* tone and the majority of these writing came from high-performance students. This raises a research question if there is any correlation between the performance of students and the tone of their writing which need further exploration. Also, being too much confident about the idea may result in over claim or exaggeration. The recommended is to avoid boasting about inventive imagination and calibrate the communication by striking a balance between expressing extreme confidence in idea and humility in creative genius.

Other dominant tones are *sadness* and *joy* which can be due to the type of problem being addressed. The ideas focused on minimizing human miseries had a sad tone and, on the other hand, ideas improving quality of life or adding luxury had joyous tone. Since these are creative writings it is bound to say things in words that create illusions or that establish a mood or other desired effects.

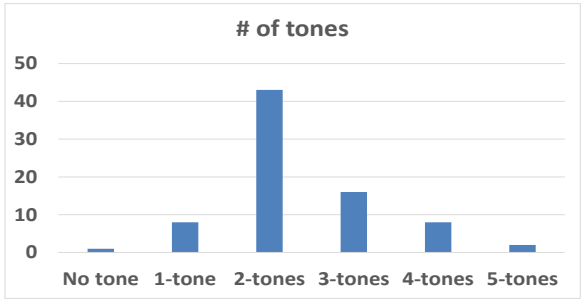

Figure 7: Use of tones in the writings

It was also revealed that many of the writings had multiple tones as shown in Figure 7. More than 42 writings (around 54.43%) have two tones and 16 (20.25%) writings have three tones. There are 8 (10%) writings each which have single tone and four tones. The students' can be informed that how by using different words in a specific way to improve the tone of their writing for conveying non-verbal observations about specific subjects [20].

VI. Limitations

This is a qualitative and exploratory study and forms the foundation of further initiatives and research. It only takes into account one specific course with around 79 students. Also, writings are rather short and might have deviation from actual score as some test may require a substantial sample of text in order to be considered a valid measure of difficulty.

VII. Conclusion

This paper reported undergraduate engineering students' ability to tune their writing according to the audiences. We found out that a large number of the students tend to write above or below the acceptable level. We also found out that majority of students' writing have multiple tones largely dominated by the analytical tone. We intend to share our finding with the practitioner in academia who can take necessary initiatives to improve students' ability to write for the nontechnical audiences. In the future, we intend to explore the reasons which made students write in a way not suited to non-technical audiences. This study found a hint of correlation between students' academic performance and tone of writing which needs further investigation.

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