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The effect of imposed word limits on academic performance in technical reports written by Mechanical Engineering undergraduate students

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Summary

Technical report writing is typically prevalent in all STEM-related undergraduate degrees including those in the field of mechanical engineering. The most common reports in a mechanical engineering undergraduate (UG) curriculum are lab and project based, although it should be noted that there has been an emphasis in recent years on reflective writing and argumentative pieces. This paper examines the different types of reports that students typically encounter, focusing on their benefit and educational premise, as well as analysing the data on the effects of imposed word limits on student performance. Technical writing skills are extremely important for engineers, but the style is very different to that which UG students have previously encountered. The curriculum at Imperial College London takes a structured approach to teaching technical report writing and provides large amounts of in-depth feedback. In a research environment, findings are presented in journal papers which often have word-limits; as such, to both manage the workload of students and staff, word-limits or page-limits with strict formatting guidance are often imposed. For a first year UG mechanics of materials lab report, students were not given a word-limit but were told that conciseness and brevity would contribute to their clarity of communication grade. As expected, those that were able to write more succinctly typically achieved higher scores. The data shows for students that did not fail that there is a weak positive correlation between the number of words used and the awarded grade up to a certain point, at which there is little or no correlation. This reaffirms the importance of succinctness in technical writing to improve clarity and reduce ambiguity. The average grades achieved in both instances were comparable (67.6 % and 66.9 % respectively) with similar standard deviations (9.4 % and 8.6 % respectively) demonstrating that imposing a word limit did not have a detrimental effect to the assessment process and allowed student performance to be differentiated successfully. This is highly beneficial to both staff and student workloads, whilst maintaining academic excellence and ensuring that all intended learning outcomes are still met.

1. Background

Clear, succinct communication is extremely important in any field or discipline and is a key skill that mechanical engineering undergraduates must develop [1]. Passow and Passow [2] performed a systematic review of competencies that should be emphasised in engineering programmes and highlighted communication. It exists in many forms, and for the most part can be categorised as written or oral. In the discipline of engineering, information is conveyed in numerous ways (e.g. engineering drawings are used to convey how a specific component should be manufactured or how a number of components should be assembled into a final product, patents outline the novelty of a device/mechanism, and technical reports detail performance and/or the findings of an experiment). Technical report writing is grounded in fact and ultimately needs to show synthesis and argumentation of information and data to make a point [3]. Therefore, educators need to provide the space for students to develop this communication skill. Oral communication is used daily in industry to delegate tasks, give updates, at conferences to share best practice, to give warnings/advice and to teach. This work focuses on technical report writing in Mechanical

Engineering and how the curriculum at Imperial College London teaches undergraduate (UG) students the fundamentals of technical report writing (including the presentation of data and findings) whilst exploring the effects of imposing a word limit on an assignment.

Scientific and technical writing is very different to the styles of writing that most UG students have encountered before commencing their studies at university. Assessment of technical communication skills forms part of the curriculum of many institutions and this is reflective of the importance of the skill. It also highlights the need for robust assessments to be developed which are able to both challenge students and support their learning [4]. The writing style of incoming students is typically verbose, flowery and structured in a way that represents humanity-based subjects. This is not surprising as the secondary education for most students does not cover technical report and scientific writing, and as such teaching of these specific skills is often required [5]. In the first year of the programme, 3 lab reports are written, this increases to 4 in the second year with the addition of a technical design report. In the third year a technical testing group report based on a 9-month long project is required, alongside a significant literature review project (~25 – 30 pages). The final year culminates with an individual research project report that details a year-long research project (depending on the electives chosen other reports may be written in the third and fourth years). The curriculum makes it clear that report writing is an important skill that must be developed to convey findings with clarity, and succinctness. This is reflected in the weighting of the final year research project report.

The quote:

"*If I had more time, I would have written a shorter letter*"

is a modern translation from that often attributed to Blaise Pascal (the French mathematician and philosopher (1623 - 1662)):

"Je n'ai fait celle-ci plus longue que parce que je n'ai pas eu le loisir de la faire plus courte"

which acknowledges the difficulty and skill involved in writing coherent, clear and succinct text with little ambiguity.

The Mechanical Engineering degree programme at Imperial College London is very structured with no choice in modules during the first two years. In the third and fourth years of the degree programme elective modules are introduced alongside core modules that must be completed. This shared curriculum amongst all students in the first two years allows convergence amongst the skill sets as large amounts of feedback can be targeted to students as individuals to ensure that the cohort is developing together (this approach removes the need for pre-requisite checks for a given module) [6]. The quantity of feedback is reduced as students progress through the curriculum to more overarching, but still specific, feedback as their self-efficacy and understanding of technical writing improves.

The three technical reports written in the first year of UG study focus on:

- Technical report writing (using Solid Mechanics as a focal point)
- Materials
- Fluid Mechanics

The four technical reports in the second year comprise:

- Materials
- Thermofluids
- Dynamics
- Design

It is worth noting that in addition to these technical reports a reflective, personal development essay is also assessed as part of students training to becoming a professional engineer. This style of report has become more prominent across engineering education in recent years and this is ultimately a result of the need for more than just the core technical competencies to meet the demands and requirements of their professional work [7], [8].

The first technical report written by the UG students details recommendations to if a hole should be drilled into a rotating arm based on the analysis of two experiments performed in a three-hour lab session. In the week prior to the lab session, the students have a three-hour seminar which details the fundamentals of report writing and presentation of data, and are provided with a number of resources to aid them in this task.

Some examples of the points highlighted are given below:

- Do not include a heading for the 'Table of Contents' in the table of contents
- Continuous data should be plotted as a line
- Equations describing trends should be a function of the variables not of x and y

In the seminar, students are introduced to best practise by sharing research published by the academic staff that teach them. This is beneficial for numerous reasons including highlighting the role of an academic and showcasing the research areas of the academics that first year students interact with. Often, less is more, and this is the message that is conveyed to students. By showing them published work we are able to demonstrate how work performed over a number of months and sometimes years is typically condensed into an article of 10,000 words or less, which details the background, experimental procedures and materials used, results and provides in-depth explanations and discussions to the behaviour observed. These examples are used to labour the point about concise communication and that the laboratory report detailing the three-hour lab session should not be more than a few thousand words.

The weighting of this first report is skewed to communication and presentation, with a less significant proportion of marks allocated to the technical content. A detailed rubric is provided to the students which not only makes it clear to what is being assessed but can be used as a self-reflective guide to what should be included in a lab report. The lab report is submitted for grading (62.5 %), marked with extensive, detailed feedback; the students then redraft the report

and resubmit (37.5 %) outlining how they have addressed the feedback given to the initial submission (this is somewhat analogous to the peer-review process for journal papers). As part of this process, given the detailed rubric that is provided to the students, a very small portion of the marks is awarded to the students correctly predicting their grade. This is done to encourage students to think critically about their report and take the perspective of an assessor. There is a strict word limit for the main body of the report and students are penalised if they fall foul of this. It should also be noted that an additional grade is provided by Imperial's Centre for Academic English for this assignment to give supplementary feedback on the use of English, grammar and punctuation (this is of benefit to all students and especially for those whose native language is not English).

The first-year student cohort (academic year 2022 - 2023) was assigned their materials lab report with no word limit; however, a small proportion of the marks was attributed to clarity of communication and students were advised to not write excessive amounts of text and think about what an appropriate amount would be given the amount of work done. Historically, the lab report had an assigned word limit but this had been removed in recent years. The lab explores the performance of aluminium alloys and the effects of carbon content on the microstructure and performance of pre-eutectoid steels. Students were asked to detail the word count of the main body of their report and an analysis was performed to determine any correlation between mark and word count. This was then repeated in the following year with a 3,000 word limit chosen for the reasons discussed in the next section. The entry requirements for the two student cohorts were the same as the students are admitted to study for an MEng degree in Mechanical Engineering at Imperial College London, and the learning experience can be considered to be uniform as all students are required to study the same modules in the first two years of the programme. As such, comparing performance data between the two cohorts is fair and reasonable given the presumed similarity in prior education based on the entry requirements and the instructors largely remaining the same.

2. Results & discussion

The pass mark at Imperial College London is 40 % whilst a grade above 60 % is deemed to be good and represents work that would result in a degree classification of an upper-second class honours (with 60 % being approximately equivalent to a 3.3 GPA).

The word count versus the % grade for 167 first year UG student material lab reports is shown in Figure 1 (a). There is an overall, weak positive correlation (Pearson Correlation Coefficient = 0.322654) which suggests that a higher word count may result in a higher grade. However, although there is a weak overarching trend, the spread of data is large and as a result this behaviour should not be taken as being causal. The data shown represents the work of 167 students. The average mark achieved in this data was 67.6 % with a standard deviation of 9.4 % which reflects that the majority of students do reasonably well in this assignment. Variability in assessors contributes to the spread of the data despite a prescribed rubric and mark scheme being used; however, it is posited that any effect due to a different marker is minimal compared to the actual difference in performance amongst students. The average word count was 3,878 with a

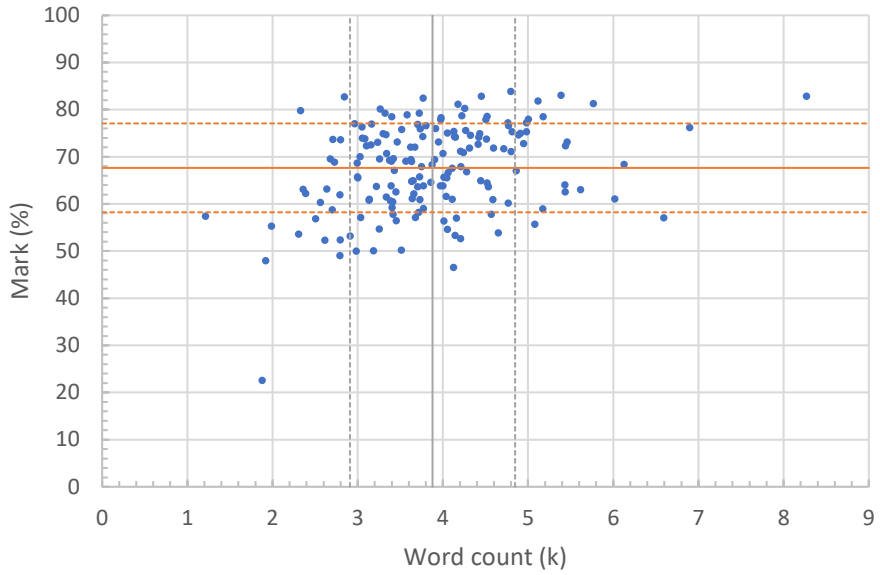
standard deviation of 969 words highlighting the large variation in length of assignments submitted. One report had a word count of over 8,000.

The same lab report was assigned to 158 first year UG students in the following academic year (2023 – 2024) but with a 3,000 word limit imposed (see Figure 1 (b)). In this instance, the average mark scored by the students was 66.9 % with a standard deviation of 8.6 %. In a similar way to the initial trend observed when no word limit was imposed, there is a positive correlation between the number of words used and grade achieved (Pearson Correlation Coefficient = 0.524738). The word count data shows that the majority of submissions have word counts of between 2,500 and 3,000 words with an average word count of 2,828 and a standard deviation of 333.

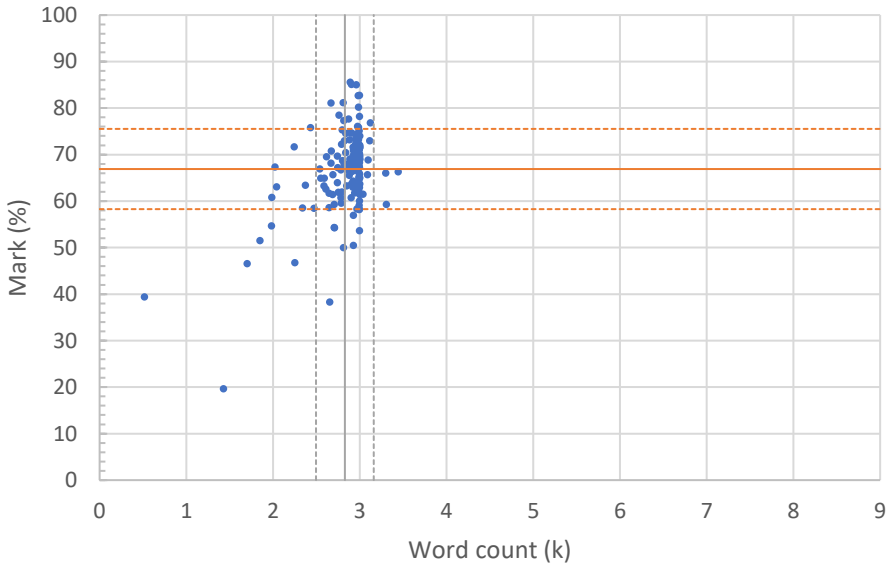
The spread of data again in the marks is significantly large. The comparable spread of grades between no word count (STD = 9.4 %) and imposed word count (STD = 8.6 %) is beneficial from an educational standpoint. This data highlights that a carefully selected word count still enables successful assessment and differentiation of students to take place as it shows that there is a sufficiently wide distribution of marks to do so and assess student performance

In both cases the importance of quality and not quantity is highlighted. Instances of a low word count and a high grade are of particular interest as it demonstrates that a well written technical report does not need to be particularly long and that the report should focus on the important detail, i.e. stating what has been done and the implications of the findings. Although, as can be seen in Figure 1, students typically required at least 2,500 words to achieve an above average grade.

In every instance, there is a minimum number of words required to successfully convey all of the required detail of an experimental investigation/laboratory class, and this has to be appropriately chosen by a module leader. The 3,000 word limit used in this instance combined historically applied word counts whilst looking at the performance of the cohort of students that were assigned the lab report without an imposed word limit. The smaller standard deviation observed in the data with a word limit is attributed to how students perceive an imposed word limit. Students often see a word limit as a target which explains the clustering of data points around the 3,000 word mark. This is not unexpected given that a word limit is typically chosen so that it gives enough breadth for a student developing their writing skills to still achieve. By imposing a word limit students have no choice but to adapt their writing style to meet this requirement.



(a)



(b)

Figure 1. Mark (%) versus word count (k) for a first year UG materials laboratory assignment with no word limit (n = 167, average 67.6 % with 3878 words), and (b) with a 3,000 word limit (n = 158, average 66.9 % with 2828 words). N.B. Solid lines represent average values whilst the dashed lines highlight the upper and lower bounds of the data (± 1 standard deviation away from the mean).

The data shows that there is a comparable spread of marks between the two data sets, yet the cumulative word count is significantly larger in the instance where no word count was imposed. This is detrimental primarily for two reasons:

- Students do not hone their writing skills and develop their ability to be selective in the information and data that they choose to convey
- There is an increased workload burden on markers with little gain to student experience and development of their skills

Providing extensive feedback at the beginning of the curriculum is advantageous to both the student and staff bodies. Students at Imperial are typically ambitious, driven and highly capable and for the most part have been the top performers at their respective secondary schools. This creates an inherently competitive environment for students when they first join, and it can be a large adjustment for students when some of their initial feedback shows grades that they might not have previously been accustomed to. The extensive feedback given at this stage helps reestablish the goal posts and reset the performance distribution that many have become accustomed to; this can be quite unsettling for many of the students yet a humbling experience too. The in-depth feedback highlights errors in the work alongside what has been done well and areas for improvement. This allows students to develop their writing with low-stake assessments so that they are able to demonstrate what they have learnt in assignments which have much greater weightings. The workload on staff is reduced as the assignments which have an extensive amount of feedback on are relatively short (i.e. compared with a final year project which is typically in the order of 10,000 words). This is not to say that feedback is not provided for longer assignments; the style and purpose of such feedback is different. At the point in the curriculum where longer assignments are used to assess skills, students have not only been provided with extensive feedback on their work to date but have also been supported in unpicking higher-level feedback and how to action these points. However, writing succinctly with clarity is a skill that takes time to develop, so research needs to be conducted to determine the additional workload that a tight word limit might generate.

3. Conclusions and Future Work

Written communication is of paramount importance to mechanical engineers. It is a skill that requires refinement and a degree of flexibility given the nature of different pieces of communication used in the practice of engineering. Technical reports are extensively used to convey findings and are expected to be of a high quality, with content conveyed in a clear succinct manner. This paper has looked at how the curriculum at Imperial educates UG Mechanical Engineering students to write technically in a clear and succinct manner.

Assignments are structured to provide a scaffold to aid the learning and development of technical writing for the students. This involves extensive feedback for shorter lab assignments in the first two years of the curriculum, which is then expected to be applied to longer assignments in the third and fourth year of the course.

There is a weak positive correlation between the numbers of words used in an assignment and the achieved grade; however, the spread of the data is significantly large and therefore the

quantity of work presented cannot be used as a proxy to determine performance. There is an assumed minimum for a given assignment to ensure that the fundamentals being assessed are adequately covered. The curriculum at Imperial demonstrates that succinct, technical report writing is an important skill to develop and can be enhanced by utilising low-stake assessments in the foundational years. It has been shown that a well-chosen word count does not affect differentiation of students allowing a significant spread of results to be achieved with a reduced marking load.

Future work aims to expand this study further and perform similar analysis on other modules whereby word limits have been imposed or reduced in recent years. Future cohorts will be asked to log the time that they spend on writing their technical reports detailing where their time is spent, e.g. data analysis, writing, refining/revising etc.

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