An Engineering Approach to Teaching Writing

Joe Miró Julià
Dept. Matemàtiques i Informàtica
U. de les Illes Balears
07122 Palma de Mallorca, Spain
joe.miro@uib.es

ABSTRACT

Being able to write correctly is a valuable asset for future CS professionals and an important learning tool, but teaching to write is difficult both for professors and students. Part of this difficulty is that writing is taught using unverifiable concepts such as style, and is significantly based on intuition. In this paper we present an engineering approach to writing, in which engineering principles are used to teach and assess writing. The results are as good, and much better in some cases, and teaching and learning become easier.

Categories and Subject Descriptors

K.3 [**Computers and education**]: Computer and Information Science Education

General Terms

Human factors

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Writing, engineering, principles, verification

1. CLARITY AND STYLE ARE NOT ENGINEERING TERMS

Communication and writing are valued skills in the workplace [7] and an effective learning tool [13] and therefore important in the teaching of Computer Science. It is being taught within the curriculum and across the curriculum in many universities [3] and has received plenty of attention in CS Education symposia. There are papers that focus on how to improve students' motivation [11], the use of communication to promote active learning [10], course organization and assessment [1, 3], or the difficulty of teaching it [5]. Despite the large number of papers dedicated to so many aspects of writing, I have found none on which writing skills (from sentence structure to argumentation) should be taught, or how they should be taught. This, it seems, is left exclusively to books on writing.

But these books are generic books, not written for scientists or engineers. It is true that they are not written for any specific discipline, but their approach and vocabulary is closer to liberal arts students than to CS ones. In my experience, this is one of the reasons writing is difficult, specially to some students, as it is seen as an elusive, foreign type of knowledge, hard to understand. Central concepts, such as clarity and style, seem arcane as they have no objective, verifiable meaning. This is illustrated with conversations such as the following, of which I have had many:

- This is not clear.
- I think it is.
- No, you see, it is too hard to understand.
- But I understand it perfectly!
- Of course, you are the writer, but a reader will find this step of your argument hard to follow
- What do you mean? It's obvious!

and so on... These conversations, where you unsuccessfully try to explain a writing concept to a student who *wants* to understand it, are utterly frustrating. You end up realizing that for some students "clarity" has no meaning and "style" is something personal and subjective, almost arbitrary. You almost believe that it is impossible to teach some students how to write competently.

You also find many professors who acknowledge that students should write better but do not know how to do it. They tell you they do not know what they should explain, how to explain it, how to provide feedback. They provide opportunities to write, but believe there is very little that can actually be taught as they consider it a personal skill that must grow from within.

It is interesting to note that this view of writing as personal and somewhat arbitrary, as arcane and unteachable, goes beyond science and engineering. One of the main points stressed in current writing books is that writing can be taught to *everybody* [8, 14]. These books make an effort to show that it is feasible to learn writing, but still present it with many references to the unverifiable clarity and the personal style. They follow, with improvements, the usual approach to teaching writing, that relies significantly on the emergence of a writing intuition. We can call this the *intuition approach*.

This approach makes teaching writing an achievable goal, but still more difficult than it should be for both professors and students. It does not eliminate the *writing anxiety* that pushes students to avoid writing [5]. This is particularly

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worrisome as when they graduate they will spend around 75% of their time communicating through reports, memos, e-mails, or in meetings with clients and coworkers [9]. Not being able to write effectively greatly reduces their future professional value.

The more I taught writing, the more similarities I found between writing documents, writing programs, and engineering thinking in general. I discovered that although writing quality cannot be measured, it can be verified, and therefore it is possible to teach writing through an *engineering approach*. This approach uses practically the same knowledge of the best writing books, but repackaged into a method with procedures and objective principles with verifiable criteria.

Using this approach writing becomes a task that produces effective documents in the same way that any engineering endeavor, with an established process, sound principles, and thorough verification produces consistent adequate products. Teaching and learning to write is easier and more palatable for both professors and students. Specially those students for which clarity is an unclear goal profit greatly.

In this paper we will explore the basic tenets of the engineering approach, provide examples of how it can be taught and assessed, and show the results obtained.

2. THE ENGINEERING APPROACH

An engineering approach to writing requires a procedure to produce the written document and a set of verifiable principles to check the quality of the product. Given that the procedure (*Researching, Drafting, Revising*) is well known and has been thoroughly and clearly described [4], we will concentrate here on the principles and verification.

The principles on which the approach is based are not new. They can be found in *Style, Through Clarity and Grace* by Williams [14], *The Craft of Research* by Booth and others [4], *The Oxford Guide to Plain English* [6], and many other books. What we show here is how repackaging this knowledge into units called *writing crafts* makes writing an engineering-like process, that makes it easier to teach and assess and easier to learn and use.

2.1 Writing crafts

A writing craft is a basic writing skill that is needed to produce a competently written document. It is formed by a *principle*, that provides specific guidance on how to write; a *rationale*, that explains why the principle aids good writing; and a *check* that allows the student to unambiguously diagnose if the principle is followed or violated.

As a simple example let us consider the structure of a sentence. A common advice, it is even written in some books, is to make sure the sentence begins well and to avoid poor endings that make the sentence "fall flat". This advice can be stated, but cannot be taught as it is impossible to assess: "beginning well" and "falling flat" are not verifiable terms. Better advice, that may be considered a principle, is to put the known information at the beginning to aid the flow and put the new and important information at the end of the sentence to finish it strongly. This is much easier to teach as students understand what "known information" and "new information" is, although the concepts "flow" and "strong ending" are vague and cause trouble to some.

This principle is not arbitrary, nor the creation of an *arbiter elegantiarum*, a judge of taste. Its rationale is based on how readers understand what they read. People pay most attention to the beginning and ends of things, and less to what is in the middle. Therefore the beginning and end of a sentence are its most important parts. Also people learn better when going from known to unknown information. Therefore putting known information at the beginning of the sentence helps the readers link what is coming to what they know. Putting the new, important information at the end, where the reader pays most attention, highlights it, making it easier to remember. This type of reasoning is not unique to sentences: all important writing principles are supported by similar cognitive rationale.

To convert this principle into a writing craft we package the principle, the rationale and the check. In this case the principle is "Put known information at the beginning of a sentence and new, important information at the end". The rationale is the one explained above. The check can be formulated in many ways. Practiced writers check it on the fly, even subconsciously, but when teaching the craft it is adequate to use a simple systematic approach such as the following. Underline the first five or six words at the beginning and end of the sentence. The underlined section at the beginning should contain known information. The one at the end, the most important new information. If they do, the principle is followed, if they do not, it is violated. This check, as is usually the case, is not razor-sharp, but is clear-cut enough to be easy to assess.

Not all principles are verifiable. Williams' first principle for concision is: "Usually, compress what you mean into the fewest words."[14, §7]. This cannot be checked. It is still a sound principle and we must stress its importance to our students, but it cannot become a craft. Fortunately, as we will see later, this does not constitute a problem.

Writing crafts are a good teaching tool. The principles are clear, the rationale show that the principles are not personal or arbitrary and help students apply them. Not having to explain what "falling flat" or "flow" is make them easier to explain and understand. Finally the checks allow the students to evaluate their own writing, help professors give valuable feedback, and facilitate assessment.

2.2 Examples of crafts

The correct structure of a sentence is a very simple craft. Let us illustrate the strength of the engineering approach with more complex ones. We will do so with two very different crafts. One is about writing technique: the correct structure of paragraphs. The other is one that would not seem subjected to principles and verification: the statement of the thesis of a paper. Below we present these crafts in a way that are easy to teach, require no vague concepts, and can be simply and systematically verified.

These crafts have been simplified, as even paragraphs are quite complex entities: one of the books mentioned [14] needs *two* chapters to explain them in detail. The rationale and principle stated here for all three crafts are much shorter and simpler than would be used in a course. The checks, on the other hand, are almost complete.

2.2.1 Paragraphs

A sentence is the minimum part of discourse that states an idea while a paragraph is the minimum unit of discourse that *explains* an idea. Explaining requires stating, therefore a correctly crafted paragraph consists of two parts. Following Williams [14] we will call the first part, in which the

idea is stated, the issue. It is often, but not necessarily, one sentence long. The second, lengthier, part is called the *discussion.* Here the idea is further explored and developed.

A paragraph is a unit, and therefore must have a common purpose that derives from the development of a single main concept. This main concept is the one located at the end of the last sentence of the issue. For instance, if the issue of a paragraph is "When a task cannot be partitioned the application of more effort has no effect on schedule", the effects on scheduling should be the only concept developed in the discussion section.

Two common errors in student papers are paragraphs with only the issue section and paragraphs without a unity of concept. In issue-only paragraphs students state the issues but do not discuss them. Fragments full of issue-only paragraphs are dry with a dogmatic tinge, as the claims stated are not discussed and thus expect the reader to accept them in faith.

As for the unity of concept, the most frequent error is to introduce a second concept during discussion. This makes the paragraph seem disperse as it develops two concepts. Also, as readers do not look for information in the middle of units, it is easy for them to miss important information altogether, and feel disoriented when the concept comes up again later.

Thus we can state the *principle* for constructing paragraphs. A paragraph is the minimum logical unit that explains an idea. It has two parts: the issue, at most a few sentences long, that states the idea to be discussed; and the discussion, that explains the idea stated in the issue. The explanation is centered on only one main concept: the one that appears at the end of the last sentence of the issue.

The *check* for the correctness of paragraphs consists of several steps. Checking for issue-only paragraphs is very simple: these are paragraphs with only one or two sentences, so all that need be done is count the sentences of each paragraph. To check for the unity of concept there is a well known technique we all use, called 'speedy reading' or 'diagonal reading': reading just the issues of a section or fragment we should get the same gist as if we read the whole fragment. We should be reading all the issues, the whole reasoning, but without the details, the discussion. For teaching purposes this can be done systematically. Cutting the issues of every paragraph and pasting them to another file creates a new text that should follow the main reasoning of the original text. 'Plot holes' or 'reasoning gaps', signalling some paragraphs are incorrect, are spotted easily once the jungle created by discussions is removed. Once the incorrect paragraphs are identified, all that is needed is to check the end of the last sentence of the issue and make sure that the concept that appears here is the only one discussed in the paragraph.

2.2.2 Thesis

Any document more than a few lines long must have a claim that articulates the purpose of the whole document. This is called a *thesis* or a *main point.* If there is no thesis at all the paper becomes an aimless rambling. Coming up with a thesis is a task that belongs to the discipline the paper is about and is not a writing craft, but stating it correctly, is. A nice additional facet is that stating the thesis correctly allows the student to assess its relevance, helping them discard trivial ideas and improve promising ones.

The two most important aspects of the craft of writing a thesis are (1) the thesis must be a relevant claim written in the paper, and (2) it must be located where it better helps the reader understand and assess the whole document.

The thesis should never be implied. For instance the thesis of Dijkstra's Go To Statement Considered Harmful is loud and clear: "The go to statement should be abolished from all 'higher level' programming languages". This claim focusses the reader for the remainder of the paper. An implied thesis, on the other hand, makes the document much harder to understand as each new piece of information must be linked to a vague frame and assessed respect to an indeterminate claim. Therefore the thesis must be written. It also must be relevant.

A claim is relevant if it encourages discussion. Relevant thesis are those that are not obviously true and are therefore subject to debate. Clearly, Dijkstra's thesis is highly relevant as many rebuttals were written claiming that go to's should not be abolished. We would also like a claim to be interesting, but that is something that cannot be checked —people differ in what they deem interesting—, so it is left out of the craft.

Two typical types of irrelevant claims students write are the *declaration of intention* ("I am going to talk about Operating Systems") and the *fact* ("Capacity of hard drives have increased over the last years"). They are not relevant because they provide us with no information —the first case— or is a fact that simply can be checked looking at data and therefore fosters no debate. Non-relevant claims, when negated, become either trivial ("I am not going to talk about Operating Systems") or false ("Capacity of hard drives have not increased over the last years").

As for the location of the thesis, it can be either at the beginning or at the end of the document. The beginning is the preferred location as the thesis will give perspective to the readers, simplify their understanding of the reasoning, and allow them to assess better the information provided. Dijkstra's thesis is in the second sentence of his letter. In a short paper the thesis can also be located at the end, as the reader can store in memory the main points of the whole paper and assess the complete argument when the thesis arrives.

The *principle* therefore is that the main thesis is a relevant claim that must be specifically written in the document, preferably at the beginning, although in short papers it might be placed at the end.

The *check* consists in looking at the end of the introductory part of a long document, or at the first few and last paragraphs of a shorter one, and identifying the thesis. If it is not there, look for it in the rest of the document. If it exists, it should be moved to an adequate location. If it does not, it must be stated.

3. CRAFT IS ENOUGH

Writing crafts simplify the professor's and students' tasks. It makes teaching, assessing, giving feedback easier. It helps students understand better the concepts involved in writing, diagnose and correct their errors. But it might seem that it does all this at the cost of obtaining simplistic, thoughtless, impersonal papers. Results show this is not so. Let us see why.

As shown above, focusing on crafts does not mean establishing a set of strict rules that students should mind-

Fundamentals: There are no spelling or punctuation errors. The paper follows the set edition rules.
Vocabulary and grammar: There are no serious grammar errors. Pronouns and ellipsis are used to avoid unnecessary word repetitions. There are no words or figures of speech that appear in the *List of Forbidden Words*. The words are used consistently with their dictionary definition. Overused words (such as *thing*) are used sparingly. In very long sentences the subject is short and the predicate has a simple structure.
Definitions y descriptions: The definitions expose the generic and differentiating traits of the object described. Descriptions are clearly ordered in time, in space or by function. In the latter, the description is ordered from the generic to the specific or from the important to the incidental. In complex descriptions, they are hierarchically subdivided to avoid having more than four or five elements at the same description level.
Paragraphs: All paragraphs have an issue section, a discussion section and a point. Only exceptionally the paragraphs will be less than three sentences long. If you read only the issues and points you obtain an adequate summary of the whole document.
Thesis: The thesis is written in the text and is a relevant statement. It is written towards the end of the introduction. The main concepts that will be developed in the paper are part of the thesis and appear towards the end of the statement.
Arguments: The argument is based on relevant statements, a logic reasoning that is easy to follow and is founded on relevant evidence. If at all possible, the evidence is data.
Story: The paper uses few main characters and few concept families. The characters and concepts are adequately introduced in the introduction section. At least one main character and concept appears prominently in each section.
Cohesion: Sentences begin and end well: the concept is located towards the beginning of the sentence and is known matter; the end of the sentence contains the most important information you want to convey. Each sentence exposes only one idea.

Figure 1: Actual checklist for a term-paper on an upper-level course. This is the concise version. Students also have complete version with detailed check descriptions.

lessly follow[1]. A craft is not just a simple command but a principle that stems from the way readers understand text, and therefore, when followed, creates understandable writing. The same way programming and software engineering principles do not excuse students from thinking when creating an application, writing principles aid the students, but do not write for them.

A good set of crafts must (1) assure competent writing and (2) be manageable. There are crafts to choose adequate words, structure sentences, produce reasonings that can be followed, generate good definitions, write clear and organized descriptions, construct sound arguments over a relevant thesis, as well as many others. There clearly are enough crafts to assure adequate writing quality, although we might not need all of them. The actual set used depends on the type of writing —short answers to questions require less writing crafts than term papers— and the writing level we want our students to have.

Also, the set is of manageable size. Figure 1 shows a concise version of the complete checklist used for term-papers in an upper-level course. One fact that helps maintain a reasonable amount of crafts is that it is not necessary to have a principle for everything. Correctly writing some parts of the discourse forces the student to correctly craft the rest. It is like a jigsaw puzzle: if you have set enough pieces correctly, the rest will fall on their own. One case is concision: using precise vocabulary, simple grammar, and correct paragraphs forces writing to be brief.

One might think that focussing on crafts, on mechanics, will produce writing that is robotic and constrained, while the intuition approach might be more difficult to master, but will produce refreshing, creative documents. Actually, if anything, it is the opposite. Following clear principles enhances creativity (as artists say, "form is liberating"). Also, once the students dominate the craft they have a sound guideline and can concentrate on the much more enjoyable task of writing something they *like*, in their own style. On the other hand, the intuition approach usually forces on the students decisions that should be personal and that *does* stifle creativity: teaching a standard impersonal style will produce standard boring papers [12].

4. OTHER ISSUES

As said in Section 1 there are many papers written through the years on how to introduce writing in Computer Science. They describe different forms of writings, student motivation, many aspects of course organization. But there are

[1]I did this many years ago and students obliged: they wrote thoughtless papers that blindly followed the rules to painful results.

some issues that are either particular to the engineering approach or must be dealt with differently. This is specially true when dealing with high-stakes writing, such as term papers. We cover these issues here.

4.1 Teaching the craft

Your students probably have been taught some of the writing crafts you intend them to master. Others will be new. The known ones require restating the principle and rationale in packaged form. This does not even require lecture time and can be done through course materials the students should read on their own. New crafts can be taught in a similar way to any engineering task: stating the principle and rationale, followed by examples, frequent pitfalls to avoid, exercises.

But in both cases the checks require a mindset change from the students and therefore need to be given special attention. Even if the basics of the checks have been shown through an intuition approach, they are presented there as a list of interesting things that can be done during revision. In the engineering approach they become a systematic set of activities that verify that the writing is of adequate quality. The change from "let's work hard and hope for the best" to "I can assure this paper is good" is new to many. This takes time and must be practiced.

One way of provoking the change is through a series of short preparatory papers. These papers, or at least the first ones, must be personally and throughly discussed. During these discussions all craft errors are pointed out against the checklist. After this craft check, style issues might appear. Students learn that they must pay special attention to craft and that they can verify their paper is correct before handing it in. These two aspects are most important to this teaching approach.

Students report that these papers are the hardest to write, and the ones that take most time. As the course progresses writing becomes easier and faster. Interestingly, this ease and speed is accompanied by a quality increase.

4.2 Exposing for style

Craft is not all: style adds personality to a paper and is an important part of making it enjoyable. To help students develop good designing taste and principles in computer architecture, Blaauw and Brooks [2] resorted to a "computer architecture zoo" of excellent exemplars. For writing that becomes a set of excellent literature.

To expose the students to style they read every week a short fragment of an excellent document. Some are famous CS papers (Dijkstra, Knuth, Hamming, Hoare are all superb writers), other are short excerpts from literature, theater, or even poetry. Just reading is too passive, so to help them cultivate their style they must select a 100 word fragment that they consider particularly interesting, copy it verbatim, and write a short commentary explaining why they have selected that particular piece. In this way they are exposed to excellent writing, they must "take it in" through the copying, and reflect on it through their comments.

Style is also discussed with students when giving them feedback on their work. Although, as explained above, feedback focuses on the crafts, it is a good moment to talk about style in a laid-back, relaxing manner. Awkward pieces are pointed out, alternatives are discussed, but always having in mind that style should not be taught: it is personal and must evolve.

4.3 Grading

Grading intensifies writing anxiety [5], so much so that some authors advocate stepping outside of grading [8, §19]. Grading only the crafts, with its objective checklist, is a less radical approach that helps reduce anxiety and frustration both for students and professors. Using crafts, grading is faster, easier, and aids learning.

Students have the checklist (Figure 1) before writing the term paper. For a paper to be good it must pass *all* the checks of the list, so a passing grade should only be awarded to papers with at most a few minor violations. Students know —or should know— beforehand if they have passed or not, and even have a good estimate of their final grade. This is very helpful in reducing the anxiety in the most productive way: producing better papers and knowing they are good.

Grading the papers is a very simple task: all that has to be done is to read them with the checklist in mind, and mark any violations. Major violations are quick and easy to spot and should mean a non-passing grade. If there are no major violations and only a few minor ones they should get a low passing grade. If there are no violations the score should be moderate to high, depending mainly on whether the paper complies with other issues that were discussed in class but are not on the list. An informal, but thorough study, shows that the writing crafts provide a fair grading in the sense that no good paper gets low scores and no bad paper receives good scores.

5. RESULTS

Let us analyze the benefits of the engineering approach in three aspects: writing quality, ease of teaching, and students' attitude towards writing.

A complete assessment of the engineering approach is difficult as it was developed very gradually over many years. To compare the benefits in these three aspects we must compare data from what happened ten or more years ago to current data. This has been possible for the quality of the writing as I do keep many students' documents from back then. It is much more difficult for the other two aspects as I do not keep old students' comments and I did not even write down my comments. For these two cases I will rely on specific happenings that, although incomplete, do shed some light.

The quality of the best papers for both approaches is very similar. The average quality has improved slightly. The main improvement is that the horrible, awful papers written by the students for whom clear writing seemed an impossible task have disappeared. This suggests that most students, those that have a knack for writing or that easily conceive an intuition for writing, will learn almost equally with both approaches. But students that simply cannot understand what clarity and style are or mean will benefit greatly with the engineering approach.

Teaching has become easier. The worst memories when teaching with the intuition approach are those of students, normally while requesting feedback, asking about concepts such as clarity or rhythm and not being able to understand them. Explanations, examples, analogies... nothing worked. No matter how much we both tried the students could not understand why their writing was wrong. It was utter frustration for all. These moments are gone. Being able to explain writing through concepts everybody under-

stands, to give useful feedback, to grade in a manner the students recognize is objective, makes me more confident and sure-footed when teaching writing. Revising, giving feedback and grading take much less time. This is clearly personal, but I am sure that many engineering professors would feel the same way.

For the reasons stated, I cannot say much about how students' attitudes towards writing have changed, but the useless, frustrating conversations have disappeared. For some students this has to be a huge difference. Knowing what to check and being able to assess their own writing is an empowering situation for all students. This seems supported by the fact that the checklist is liked and considered helpful.

Summarizing, the engineering approach produces results at least as good as the standard one, and for some students, much better. Teaching tasks, specially giving feedback and grading, has become simpler and take less time. Students probably feel more empowered and less reluctant towards writing.

Finally, there is a phenomenon that I would like to comment on. Since I began introducing writing in my teaching I have often received comments from grateful students in which they stated that learning to write had been very useful to them. Up until a few years ago they were always general comments: "I've had to write a lot. Taking your course was very useful." Now I receive one or two accounts a year of specific instances in which writing has been useful to former students, be it in other courses or in their jobs. These accounts all focus on how they applied the crafts to solve specific writing problems. It seems that with the engineering approach writing is more than something "generally good;" it is specific knowledge that can be applied when needed. This is significant because one usual complaint on generic writing courses is that the knowledge the students acquire does not transfer easily to other settings [15]. It seems that crafts transfer to other writing much better than intuition.

6. CONCLUSIONS

The engineering approach, with its writing crafts, is a new method to teach writing that is closer and more palatable to the engineering community. Students, specially those for which which the world of writing is alien, understand communication better, sense that they can control the quality of what they write, become capable of writing adequate papers. Professors can explain, give feedback and grade in a simpler manner and using less time. The mindset of writing with this approach is closer to other engineering activities, and should make it easier to integrate writing into other engineering disciplines. Also, professors should feel less reluctant to introduce writing activities in their teaching.

Comparing teaching approaches and attitudes of students and professors is notably difficult. Although we all know what "good writing" is, comparing writing results is problematic. Is the engineering approach a demonstrably better method for teaching writing? Is it useful outside of science- and engineering? Answering this would require a multi-year, multi-college effort. If you are interested, let me know.

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