Improving the Writing of Engineering Students through Portfolios

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Abstract

The Department of Civil and Natural Resources Engineering, University of Canterbury, New Zealand, has trialled the development and assessment of student writing, sketching, and oral presentation skills through a compulsory portfolio approach. Rather than rely on a dedicated communications course, students are required to improve their skills using assessed work from their professional courses. Students must take samples of their work and refine them prior to submission as a portfolio item. Students are supported with comprehensive written guidance, workshops, and one-on-one tutorials. Students must pass a 0 credit, pass/fail Communications Portfolio course before proceeding to communication-intensive courses in Year 4. Students who fail can either wait a year and resubmit, or pass a non-university summer course in technical writing at their own cost.

The focus of this paper is on the development of writing skills within the broader Communication Skills Portfolio course. The motivation for this innovative approach is described in this paper, along with the structure development of the programme, the involvement of practicing engineers, and preliminary outcomes. The trial has taught us that student work must be tied to professional report practices and practicing engineers must be involved in delivering the message. Despite intensive workshops and advice, only 8 out of 43 portfolios were judged to have met professional expectations. One key finding of the investigation to date is that students need more advice and practice at error checking. The Department has the full support of employers to keep the pass bar high and to fail students who do not demonstrate competence with their standards. Results of the 2012 portfolios (submitted in November 2012) will be provided at the conference.

1. Motivation

Engineering graduates need to meet the high expectations the profession has for strong writing skills and other communication skills (e.g. oral presentations, and drawings). Though similar to the communication skills required by scientists and technologists, engineers are expected to master significantly different communication skills than other university students. For example, engineering students need to learn how to write succinctly and objectively with a passive voice. This change in writing can mean that students may need to unlearn some of the writing skills they acquired before entering an engineering degree.

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Teaching of writing skills can be, arguably, the most difficult communication skill to teach. Engineering students need to master writer, genre, and reader-oriented composition, though not necessarily to equal levels or at the same time. In Years 2 and 3, engineering students need to master 'genre-oriented composition'; in other words, they need to be able to match the expectations for diverse, yet specific, writing types: cover letters, laboratory reports, design reports, engineering drawings, and oral presentations. In Years 3 and 4, engineering students, to varying degrees, need to focus more on reader-oriented composition and recognise the distinctions that result from the variety of readers they will have (other engineers, clients, affected citizens). In Year 4 and in professional practice, the emphasis shifts more to writer-oriented composition. It is at this stage that writing becomes linked to reflective practice as part of the step that engineering students take towards the life-long learning required of professionals (Schon, 1983, 1990).

Although the process of developing writing skills is applicable to all engineering degrees, it could be argued that the challenges are greater for civil/environmental engineering educators who teach writing. These graduates need to write not only for other engineers, but also for clients and affected citizens. This diversity of audiences complicates the process of teaching writing to engineers. Development of communication skills is central to the education of civil and environmental engineers. Although this paper describes an approach implemented for civil and natural resources engineering students, much of the analysis can be applied to other degree programs.

Employers commonly identify communication (particularly, writing) skills as the greatest weakness of our engineering graduates. A typical comment from a faculty member in the department reads:

> *In my opinion most [of our students]… are absolutely terrible writers probably because we have encouraged those students who are good in math and sciences to come into engineering rather than those students who are good in maths, science and English. No matter how much we emphasise that writing is important, it is not until they get out to work that they get a shock when the employers tell them how terrible they are. They simply don't believe us.*

Our Advisory Board (comprising employer representative from industry) highlighted poor writing skills as the greatest weakness of our department's graduates, while also recognising that this problem is increasingly severe with engineering graduates they hire from other universities. Increasingly, engineering firms in New Zealand organise in-house courses for new engineers on engineering writing. The Institution of Professional Engineers New Zealand (IPENZ) often runs courses for graduates on "Effective Report Writing for Engineers". As another example, a two-day course run in Wellington by BrightStar in 2010 on "Report Writing for Technical Professionals" cost NZ$2000, indicating high market demand for improving writing by the broader technical professional sector. Anecdotal evidence indicates that civil and environmental engineers are becoming less prominent in aspects of multi-disciplinary engineering projects where communications skills are critical—bidding documents, permit/consent applications, financial project assessments. The message university engineering educators receive is very clear: improvements must happen or the value of our graduates will suffer greatly.

On the other hand, in our exit surveys students rate their communication skills as one of their educational strengths. Our graduates were asked how well they believe their education

prepared them for each of the attributes of our engineering graduate profile. For graduates of 2007 and 2008, "communication and writing" scored 4.0 (on a scale of 5), which was the third highest of 10 attributes, outscoring "Ability to understand and apply engineering sciences (3.6)" among other attributes. Perhaps unlike North American students, our students either do not believe that engineers need to be good writers, or are convinced that their writing skills are already adequate. It is relatively easy to address an education problem when students admit that they have gaps in their education. It is a much more difficult matter to improve education when students do not see that their current education is deficient. This disconnect between employers and recent graduates justifies our bold new initiatives.

Some background context is needed for our specific situation. We operate two Bachelors of Engineering degrees: civil engineering and natural resources engineering. The latter is a combination of environmental, agricultural, and water resources engineering. For the two degrees, we take in approximately 180 students per year. Prospective engineering students must spend their first year at university in engineering/science courses, and then apply for admission to the three years of the Engineering School. We have roughly 5% overseas students, 30% women, and some of the brighter students in the country. Students have all required courses in Years 2 and 3, with 3/8 required courses in Year 4, and 5/8 optional courses in Year 4. Excepting the students who fail courses, most students are taught as a cohort through Years 2, 3 and 4. This means that we can and do exert significant co-ordination between courses to balance workload and ensure consistent treatment of various topics. Our degrees are accredited every five years by IPENZ. The degree is assessed based on our ability to meet a number of graduate attributes, similar in many ways to the ABET process. We have not received comment for change in our approach to teaching of communication skills from past accreditation boards. We have relied on various communication skills being taught in one or another required course. These particulars need to be noted because they can make it difficult to extrapolate our experiences to other engineering programmes.

Our two new compulsory courses (Project and Professional Engineering Development) will require stronger communication skills of our students. O'Sullivan and Cochrane (2002) comment on the strong key role that communication skills have in our project course. To allow for success in these Year 4 courses, writing skill improvements in Years 2 and 3 are urgently needed. Rather than fail students in Year 4 courses because of weak communication skills, our department agreed that a pre-requisite level of communication skills would need to be reached before entry into these required courses.

A great body of knowledge exists on teaching of writing skills. However, much of it does not seem relevant to the university education of professional engineers. Other engineers have highlighted the difficulty in applying the literature on teaching of writing skills to university engineering education. For example, Robinson and Blair (1995) note that, "… much of … [the literature is] conflicting and not all of it relevant to the writing requirements of [engineering] disciplines." Much past work on teaching writing to engineers (eg, Beaufort, 2007) seems to come from the viewpoint that simple adaptations of methods used in the Arts will be sufficient to allow engineers to reach communication goals. Our assessment is that a distinctive approach is needed: one that focuses on the specific communication tasks faced by practicing engineers, and one tightly linked to employers' expectations.

Methods of teaching writing skills that focus instruction on the requirements of different specific types of writing are often called genre-oriented approaches (Walker, 1999). Although

critics dismiss these approaches as taking a cook-book approach to teaching writing, they have the distinct advantage of being goal focused, which helps in convincing reluctant engineering students to put in the effort to improve. Universities as diverse as M.I.T. (Paradis and Zimmerman, 2002) and Curtin University in Australia (Grellier and Goerke, 2010) have developed Writing Style Guides with a clear dependence on a genre-based approach to teaching communication skills. Grellier and Goerke (2010) go so far as to use the metaphor of a tool as a way to emphasise how engineers will use unique document types for specific purposes. Contextual learning, and hence genre-oriented teaching of writing, is particularly important for engineering students because they are characteristically practical-oriented learners.

Too many engineering students arrive at university convinced that either they cannot write or do not need to write. Engineering education needs to move beyond classing students as 'bad' writers, and instead treat them more as 'uninitiated' writers (Fernsten and Reda, 2011). Genre-oriented approaches help to emphasise that learning writing is learning a set of skills.

Recent research in engineering education has emphasised the importance of involving industry in education (e.g., Lamancusa, et al., 2008). A tight link between improved teaching of writing and employers' expectations matches calls for more professional links for engineering students. This call is both strong and multi-national (ASCE, 2004; King (Aust.), 2008; Royal Academy of Engineering (UK), 2007a, 2007b; U.S. National Academy of Sciences, 2004).

2. Departmental Stocktake

2.1 Goals

The Department considered the graduate profile (as set by our accrediting body, IPENZ) and the abilities of incoming students to set year-based communication goals for its graduates. Because of our decision to assess Portfolios based on communication skills developed in Years 2 and 3, we focused on those needed at the end of Year 3. These are shown in Table 1.

2.2 Analysis of grammar errors

In order to better understand the skills of current students, a number of assignments were examined by a co-author with extensive experience of advising students on ways to improve their writing. The analysis indicated that grammar issues were much more serious than subjective issues such as structure or overall logic or clarity (though there were issues with these as well). Knowing that it would be impractical to teach all the grammar rules to all students, a count was made to see which errors were most common. The most common errors were:

- Spelling mistakes
- Run-on sentences (two independent clauses run together)
- Comma splice (two independent clauses joined by a comma)
- Sentence fragments (phrases or dependent clauses treated as sentences)

Combined, these errors were over 50% of the total grammar issues. These four dominated over other issues such as: mis-use of articles, confusions over which/that, delayed verbs causing reading difficulty, mis-use of capitalisation, apostrophe errors, errors of subject/verb agreement, mis-use of verb tense, mis-use of pronouns, inconsistent use of the singular/plural, and mis-use of colons and semi-colons.

Table 1. Communication skills expected of students after Year 3.

Skill
Manage large sets of raw data and use graphical display
Extract concepts from variety of reading materials
Locate reference resources
Extend laboratory reports to an appreciation of implications and research potential
Develop support for arguments in an engineering context
Write an engineering report for a non-engineer client
Write effective instructions and diagrams in an engineering context
Use word-based answers to calc. problems with well documented calcs. in appendices
Deliver a short yet structured oral presentation
Read engineering practice documents (design codes, standards)

We believe it significant that these four most common issues all indicate deficiencies in the foundations of communication. They were not 'pedantic' errors of minimal real-world consequence; rather, they were signs of basic literacy problems.

2.3 Student survey

Before the start of the portfolio program, Year 2 students were surveyed on their attitudes to writing. The response rate was 122 out of 180 students. In response to the question, "How do you rate your writing ability?", the responses were:

7% poor (my major weakness)
30% acceptable (needs work, maybe a little below average)
57% good (at least average in my class, but room to improve)
7% very good (well above average in my class)

Another question asked, "How do you revise your writing before you hand it in?" The responses were:

4% I don't really revise it at all

30% I revise as I go
55% I proofread it when I've finished
6% I ask a friend or family member to proofread it for me
5% Other; please specify
"Generally finish last minute and lose marks for stupid mistakes"
"spell check"

The results, though indicative only, indicated to us the mismatch between student views towards their writing and those of employers, and also provided insight into the lack of revision skills.

2.4 Diagnosis of deficiencies

Our former across-the-curriculum approach to teaching communication skills had a number of deficiencies, which were highlighted by the examination of student work. These were:

- Students were partly assessed on communication skills in each course, but never so much that it was a key determinant for the final grade; as a result, an improvement in weak communication skills had not been demanded.
- Faculty gave students inconsistent messages about the expectations for each type of report (eg, laboratory report, assignment); this had limited the impact of the instruction that was carried out independently in each course.
- There was no co-ordination between courses and so no logical progression for students.
- There were few or no questions related to communication skills in examinations; this reinforced the student perception that good writing was less important than good quantitative skills.
- We increasingly used group reports at higher levels, which made it more difficult to show individual competence at essential communication skills.
- Students were not shown the relationship between communication exercises in their coursework and the communication expectations after they graduate and are in practice.

3. A Portfolio Approach

Two predominant approaches to teaching communication skills to university engineering students exist. One approach relies on formal communication courses. The other method could be called an 'across-the-curriculum' approach, where communication skills are advanced in a systematic way by introduction into courses throughout the curriculum.

Because the majority of our engineering students are taught as a cohort, with most students taking the same courses at the same time through Year 3, it is theoretically possible to provide effective co-ordination with this latter approach. However, there had been no clear way to assess communication outcomes and ensure attainment of our goals prior to Year 4.

Our Department's faculty considered the option of a separate communications course, but was very reluctant to move in that direction based on observations of ineffective outcomes at universities that operate using this approach. The perception is that the courses do not effectively link communication skill development to engineering practice requirements. The reasons appear to be (1) the courses are taught by non-engineers, and (2) the courses develop negative stigmas (partly because of faculty impressions). Consequently, students perceive that the 'writing' course is not central to their study. In addition, our diverse student intake means that a small number of very strong students need minimal assistance to meet near-

professional writing standards, and a requirement for a communications course could easily lead to resentment by strong students.

We see our Portfolio approach as a middle, 'third way'. Architects and Fine Arts students often have 'Portfolio Assessment' of their work to support their overall educational development. During these Portfolio assessments the students are asked to provide samples of their best work and an overall assessment is made. We believe a Portfolio approach for assessment of communication skills would give co-ordination while reinforcing that this is improving students' value to employers.

The Portfolio approach we have developed requires students to resubmit particular pieces of coursework at the end of years 2 and 3. Rather than being assessed on their technical quality, the Portfolio reassessments are purely on the basis of specific communication objectives. The objectives incorporate both writing skills and document presentation—the latter being seen as a critical aspect of technical communication by engineers. Our Portfolio approach emphasises cross-course communication with students about Portfolio requirements.

This Portfolio approach will help us to introduce novel (for engineering education) requirements for resubmission of work, and to structure tuition and workshops for students in need. At the same time, there is potential to tie writing to workplace expectations through provision of sample work and development of a Guide to the writing of key workplace outputs.

A great deal of support and goodwill exists at our university to improve the writing of engineering students. The Learning Skills Centre provides occasional lectures on writing for students, and also provides extensive advisory services. Individual lecturers devote course time to improve writing skills, and ensure good feedback to students on their weaknesses. Before the Portfolio program, however, there was no appropriate or inspiring structure for these initiatives.

Currently, the six items in the communications Portfolio are:

a. Sketch (from Year 2 Timber Design course)
b. Laboratory report (from either Year 2 Transport or Materials courses)
c. Reasoning report (a qualitative assessment of environmental effects from Year 2 Environmental Engineering course)
d. Client report (from Year 3 Design course)
e. Calculation-rich report (from Year 3 Structural Analysis or Programming courses)
f. Oral presentation (discussing one of the above Portfolio items using a recorded presentation software package)

The advantages of ensuring that a small number of items are submitted to a very high standard, from our viewpoint, are:

1. It develops students' (currently weak) skills in revising their work by focusing on specific items.
2. It mimics professional practice.
3. It produces student work samples that can be shown to potential employers.

The Portfolio is formalised as a 0 credit, pass/fail course that is a pre-requisite for required Year 4 courses.

4. Portfolio Programme Components

4.1 Lectures, Workshop, Tutorials

Direct support for students preparing their portfolios comes in the form of two hours of lectures, a one-hour workshop, and a three hour one-on-one tutorial session. All of these are optional for students. The focus of the lectures and workshop varies between Years 2 and 3. For Year 2 students, the focus is on sentence-level writing and presentation, and the weaknesses noted in 2.2. For Year 3 students, the focus is on style issues and ways to improve their writing for longer reports. We have found it useful to provide a workshop immediately after the lectures, and in the workshop have the students form small groups and work on relevant exercises. The intention with the lectures and workshops is to give students advice that will help them to develop skills for their portfolio and, consequently, for all course submissions. All teaching materials are available for all students through an electronic course assistance website.

The tutorials are organised to occur just before the Portfolio items are due, and they focus on helping students to revise drafts so that they can meet Portfolio standard. We operate these at a ratio of 1 tutor per 60 students; of the 60 students, roughly 40 students appear at some time during the optional tutorial. The sessions last for three hours, but most students who arrive are there less than one hour. A mix of engineering and arts graduate students has worked best as tutors.

4.2 Involvement from engineering practice

We advertised locally for a 'Writing Mentor' from the engineering community. Our choice proved to be an experienced consulting engineer who in recent years has given lectures to incoming employees on writing. His assistance has proven very valuable. We have organised for him to give a one-hour lecture to our Year 2 students on the importance of good writing in civil and natural resources engineering graduates. His advice includes the following reasons why students should improve their writing:

- Nearly all the technical specialists and managers in engineering organisations are good writers.
- Senior engineers have to interact with other professionals such as lawyers and planners who are good writers.
- When editing and revision time is reduced, the organisation's costs are reduced.
- Communications have legal standing when disputes arise.
- As a good writer, you will receive better grades while a student and, because your supervisors will be impressed, you will receive faster promotion when employed.
- If you want to be paid at professional salaries, then your writing has to be at a professional standard.
- Improvement in writing skill indicates a positive attitude towards continuous learning. It is an on-going journey. Enjoy the challenge!

In addition, our Writing Mentor arranged for the students to receive copies of reports similar in style or intent to the Portfolio items. The writing mentor provided copies of reasoning reports, client reports, calculation-intensive reports, and engineering sketches. The Portfolio co-ordinator analysed these professional reports and highlighted to students the similarities and differences to corresponding student report types.

4.3 Assessment

Assessment has been organised around the six submissions (see 3.), and all six submissions must be at Portfolio standard. Significant presentation flaws (eg, no figure captions, poorly

formatted headings) result in a failure. In addition, five 'fatal' flaws lead to failure; their maximum number allowed per assignment are—

a. Spelling mistakes (4)
b. Comma splices (2)
c. Run-on sentences (2)
d. Sentence fragments (2)
e. Faulty parallelism (2)

The last one, although not one of the most common errors in student writing, has been included because of the common use of lists in engineering report writing, and because it draws students' attention to differing grammatical forms.

In addition, to pass Portfolio an overall assessment of the student's communication skills must merit at least 5 out of 10. The overall assessment of students' communication skills was needed to catch students who avoided the issues above, but who nonetheless either make large numbers of other sentence-level grammar errors, or who exhibit major style problems. Either of these problems would decrease their ability to pass our required Year 4 courses. The Portfolio co-ordinator has taken advice from our Writing Mentor and other faculty to develop a qualitative ranking method to use for the overall assessment.

All students are given written feedback by tutors. The markers have been a mixture of engineering and arts graduate students. We have found it useful to trial tutors in the one-on-one tutorials, and then use the better ones for Portfolio grading. A significant amount of oversight by faculty is needed in the grading of portfolios. Maintaining consistency is a key concern, particularly in determining the pass/fail line.

Students who fail their overall Portfolio at the end of Year 3—either by having (1) one or more unsatisfactory items, or (2) an overall assessment of less than 5 out of 10—are able to resubmit. The resubmission is assessed in the same way as the original submission. Students who fail the resubmitted Portfolio will be required to take and pass a non-university summer course in technical writing. The summer course has yet to be arranged, but there are multiple providers for such courses, and we would anticipate a cost of roughly $1000 per student for a week-long course. The Portfolio course is not an assessment of their communication skills at graduation. Students who pass Portfolio must still demonstrate competence at the Bachelors level in their communications-intensive, Year 4 courses.

4.4 Outcomes of trials

The 2011 trial was with Year 2 students. Students were not required to submit portfolios. Of the 180 students,

- 140 attended the lectures
- 30 attended the workshop
- 27 attended the one-on-one tutorials
- 43 submitted portfolios
- The average overall assessment was 7/10 with only 3 of 43 below a passing grade of 5
- 5 portfolios passed while 38 failed because of 'fatal' errors

The low pass rate was revelatory, but not wholly unexpected. A closer look showed that roughly 40% of those who submitted would have passed with better revision of their work. These students made simple errors that they would be able to correct if they were better able to look closely at their own work. Roughly 40% seemed to need more effort to meet the

Portfolio standard, and simple error-checking would not likely be enough for them. Only 10% were likely to need major additional effort in order to meet the high standard set.

Further analysis of the results showed that students with English as a second language were not failing the Portfolio at a significantly higher rate than native English speakers. The 2011 trial had a high number of these students submit their Portfolio voluntarily. This indicated to us that these students appreciate the need to improve their English and are willing to make the effort to do so when they know that support is available.

The high failure rate led us to reassess our standard. We checked with our Writing Mentor, and he believed the bar was set at an appropriate level for entering graduates.

For the 2012 trial, the Portfolio submission was still optional, but it was made clear to Year 2 students that they should submit three items in 2012 so they only need to submit three in 2013 (when the Portfolio has become mandatory) rather than all six. Of the 180 students,

- 160 attended the lectures
- 30 attended the workshop
- 65 attended the one-on-one tutorials
- 170 submitted portfolios

Marking of the 2012 Portfolios is still underway, but it seems that there will be fewer than 10 passes for this portion of the Portfolio. Clearly, we have a long way to go.

4.5 Communications Portfolio Guide

During the development of the Portfolio programme, it became clear that students would need consistent reference materials to consult when submitting their Portfolios, but also when producing reports for their regular coursework. It was important that the students have one authoritative style manual that would apply for the whole Department. After developing a number of individual guidance documents for various specific purposes, we decided to compile them into a printed book. A printed book has the advantage of being definitive and easily referred to by faculty and students alike. A series of on-line, continuously updated documents ran the risk of confusion by students over which version or document should be consulted and when updates had been posted.

Our Guide is roughly 120 A4 pages (Department of Civil and Natural Resources Engineering, 2013). It has been spiral bound to make it easier for students to use it while at their computer workspace. To help with Portfolio submissions, it has a number of check-lists for students to refer to. The check-lists have proved valuable for the one-on-one tutorial sessions leading up to Portfolio submissions. In addition to specific advice directed at the Portfolio requirements (covering the Department's agreed presentation standards and key aspects of effective, accurate, and error-free writing), the Guide also contains advice on writing the different types of assignments, including laboratory reports, client reports, calculation-rich reports, and engineering sketches. It also has a chapter on short professional communications that gives advice on how to take meeting minutes, compose emails, and how to meet professionals and faculty in their offices. The Guide even includes advice on how to answer short-answer and essay questions that students might find on examinations. The Guide uses a large number of student-relevant examples and makes frequent reference to the expectations of the engineering profession.

For our department, which already prided itself on the way individual faculty would teach communication skills within their courses, it has been a serious exercise to develop one book

that everyone would adhere to and use. Because students no longer need to adjust their writing for individual faculty, it has become useful for them to develop report templates in Word that they can use for multiple courses. The Guide developed through the goodwill and dedication of faculty, and we hope it will be used for a few years before its inevitable revision.

5. Conclusions

Our Portfolio approach, after two years of trials, will have its first full implementation in 2013. You might hear the students' cries of anguish when the 2013 failures start impacting on their ability to graduate. The key questions we still face are:

- Where to set the pass/fail bar for Portfolios?
- How to improve students' proof-reading skills?
- How to build on the Portfolio platform in Year 4 courses?
- How to get a faculty member to agree to lead the programme when everyone will point out that person's communication errors? ☺

A question we have resigned to leave unanswered (for now at least) is: how much better educated are our students because of the introduction of Portfolios? We do not have strong data on the performance of students before the curriculum changes, and we have such a serious situation with respect to weak writing skills that we cannot justify retaining a control group who do not go through the Portfolio process. Although far less than ideal, we will need to rely on the feedback we receive from employers and a comparison with students in other engineering degrees who do not have a Portfolio requirement.

After two years of hard effort, the Department remains resolved that the Portfolio approach will work for us. Its key advantages are:

- It mimics professional practice, increasing student buy-in
- It accommodates a widely varying ability of incoming students
- It retains communication skill development in many engineering courses
- It allows for co-ordination and quality assurance
- It provides students with outputs that they can show prospective employers

The Portfolio approach has excellent potential for departments looking for another way to teach communication skills. Although some aspects have been specifically tailored for civil and natural resources engineering students, most of it could be readily transferred to other engineering degrees. Within the University of Canterbury, other engineering departments are very interested to see the result of our trial, and there has been contact with our Bachelor of Arts faculty who see a need to properly assess writing skills without a communications course.

Some of our important lessons bear emphasis. The buy-in of faculty is critical, as for any approach to improving communication skills. The gap is very wide between employers' views of students' communication skills and students' perception of their skills, which means that it is especially challenging to get students to take seriously the need for improvement. We have found the links to employers and mentors critical throughout the development of the Portfolio. As with any major effort at curriculum change, the portfolio development has required significant effort, and has led to its share of unforeseen indirect effects that have needed careful management. In spite of these issues, the Department believes the Portfolio approach will provide a step change in student communication skills.

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