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Online Approach to Teaching Report Writing in Chemical Engineering: Implementation and Evaluation*

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Although interactive computer-based learning approaches are common in engineering education, this approach has rarely been used to teach writing skills. This paper reports on an interactive online program that aims to teach report writing in chemical engineering. The development of the program is discussed together with its integration into the curriculum. Finally, evaluation approaches and analysis are presented. Although the overall evaluation was positive, questions are raised about how to improve student confidence in writing, help students transfer their learning to other writing contexts and use their writing to deepen their knowledge of engineering subject matter.

Keywords: report writing; communication studies; chemical engineering; computer-based learning; laboratory feedback

INTRODUCTION

ONLINE AND COMPUTER-BASED approaches to engineering education have multiplied over the last decade and have created a flexible and versatile learning environment for students. In particular, computer and Web-based resources have proved to be useful tools in providing virtual laboratory and project learning experiences as well as delivering course content and developing numerical, computer and technical skills [1–6]. However, the main emphasis in these programs is the development of the students' knowledge and understanding of engineering subject matter and associated mathematical and technical skills rather than the communication of this information through writing.

Communicating effectively in writing has long been recognised as a critical skill for engineering students to master [7, 8], and employers, accrediting bodies and graduates have emphasized the need for high level communication skills for professional practice especially in terms of improved job opportunities and career prospects [9–11]. However, improving students writing skills continues to be an ongoing challenge for lecturers, despite a number of successful approaches to developing writing skills in engineering courses that involve both the product and process of writing. Although laboratory report writing remains a key genre for both engineering students and graduates [12], the importance of setting a variety of written tasks for assessment, such as writing for journals or technical newsletters, has been emphasized, as well as genres that reflect professional practice, such as memos and product descriptions or instructions [13, 14]. The process of writing can be enhanced by collaborative approaches, peer or mentor feedback and editing where mentors are drawn from the professional engineering community and portfolio building, which creates a sense of continuity among writing tasks and can make feedback more effective [13, 15, 16]. Such approaches go together with new ways of teaching, many of which involve collaboration between engineering and language and learning lecturers and where writing is closely integrated into an engineering curriculum that incorporates aspects of problem-based learning [15, 17–19]. However, the potential for using computer-based resources or the Web for teaching writing, in particular report writing in the context of engineering laboratory work, remains largely unexplored.

Although information on report writing and example reports exists online [20], these programs do not contain interactive exercises or feedback, so students cannot check their understanding of the information or their development of report writing skills. In addition, although virtual laboratories have the facility to generate reports automatically based on students' calculations [21, 22], there is little exploration of issues such as the purpose of the report and how this is reflected in its structure

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and language. In this paper we will discuss the development of an online program for laboratory report writing that has been integrated into the chemical engineering curriculum. This program not only provides discipline-specific explanations, guidelines and examples, but also includes interactive exercises and feedback. We conclude with the evaluation of the program and its outcomes.

APPROACH

From the beginning an integrated and collaborative approach was adopted to teaching report writing skills in the chemical engineering curriculum. This teaching approach has been successfully used in a number of other discipline contexts both at Sydney University and in other tertiary learning situations [15, 18, 23, 24]. Collaboration between subject area specialists and language and learning specialists in the teaching of writing skills ensures that both the discipline knowledge and ways of communicating that knowledge are addressed in the curriculum and in the teaching/learning environment whether on or off line. Initially, the report writing program was taught face-to-face using print-based materials and was integrated into the third-year chemical engineering laboratory course, a semester long course that involves students in group-based laboratory work and assesses each student individually based on their laboratory report. The report writing program aimed to make explicit to students the genre, discourse and language requirements of the laboratory report within the disciplinary context of chemical engineering. This approach to teaching writing skills, usually termed genre-based literacy pedagogy, is widely acknowledged as effective and is used in tertiary learning contexts as well as school and workplace situations [25, 26]. Genre-based literacy pedagogy and related approaches have also been used to teach the genre of the laboratory report [27–29]. The teaching materials, such as authentic student example reports, which were used successfully in the classroom situation, were adapted for the online program.

The pedagogical design of the program reflects constructivist and phenomenographic approaches to learning that have been influential in the development of online learning environments [30, 31]. The typical stages of a laboratory report were used to create the macro-design of the program, together with a section called Overview, which addressed issues such as the structure of the report as a whole and typical problem areas in report writing. Within each stage, explanations, examples (of a range of reports displaying both strengths and weaknesses) and interactive exercises followed by feedback were used to help students understand the appropriate content, structure and

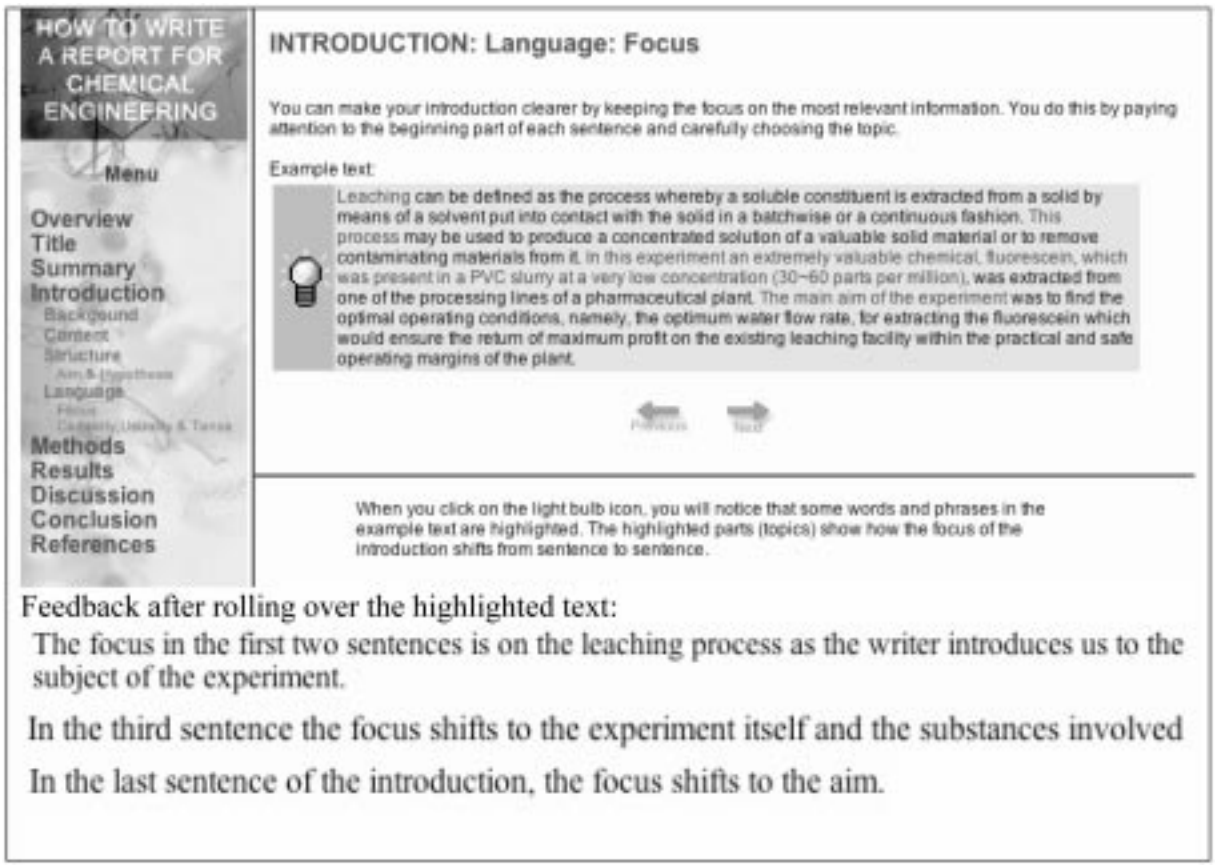

Fig. 1. Example of the use of highlighted text and hotspots to illustrate language features of the Introduction stage of the laboratory report.

language features of that stage. In addition, a diagnostic exercise was included at the beginning of each stage (the Background section, see Figs 1 and 2) so that students could check their understanding before deciding whether to continue or move to another part of the program. Although the program was integrated into the third year chemical engineering curriculum, it has been designed to stand alone for self-directed learning so that it can be more widely used within the Faculty of Engineering. Another important design feature has been the development of reusable templates for the explanation, example and exercise screens (using Dreamweaver and Flash) and this has allowed us to extend the program in a more cost effective way to create two other laboratory report writing programs in biochemistry.

An online medium for teaching report writing

Although an online medium cannot replace the rich environment of the classroom experience, it can provide a number of advantages for teaching about writing in the disciplines. First, as with other online programs, students can access the program in their own time, at their own pace and according to their individual needs. These advantages are especially useful for a program on writing as student needs will vary considerably in this area given the diversity in language background and educational experience of today's student population. Secondly, the online medium can provide more visually dynamic explanations and examples of text features. Although this cannot be compared to the three dimensional animations or simulations which can illuminate engineering concepts [32], nevertheless these active screen displays with hyperlinks or hotspots can show how different features in the text combine to create the meaning and purpose of the text (see Fig. 1).

In addition, the integration of interactive exercises with immediate feedback into each part of the program means that students can check their growing understandings of the content, structure and language of a report (see Fig. 2).

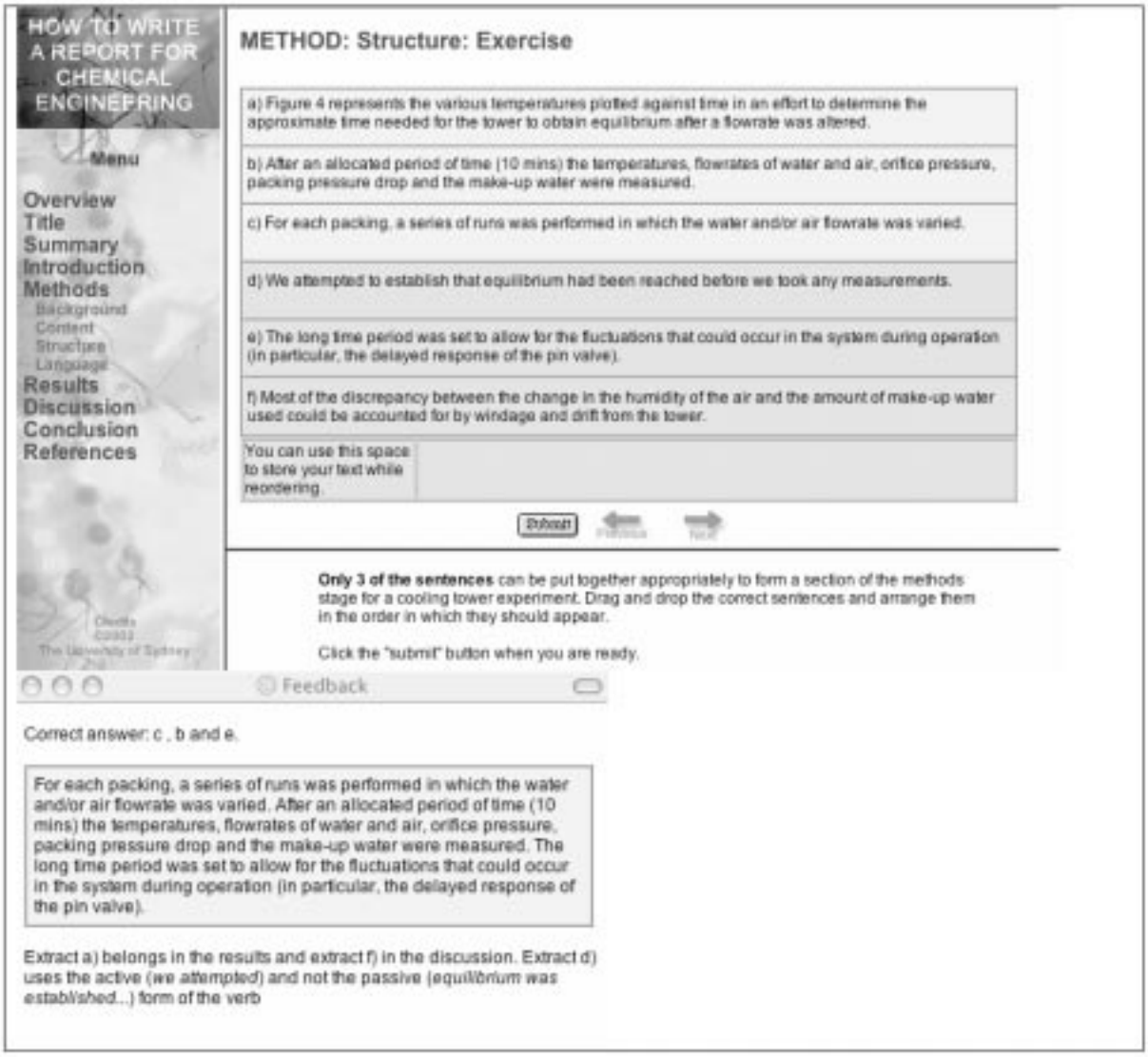

Fig. 2. Example of interactive exercise and feedback from the Methods section of the laboratory report writing program.

However, exercises are limited by the online nature of the medium to basically multiple choice, true/false and drag and drop and there is no opportunity for students to engage in extended writing, for example, to improve an example report, as feedback cannot be provided immediately for this kind of exercise and can only be given by lecturers via email. In addition, feedback is not adaptive to students' levels of understanding of the material, nor can the program simulate the iterative classroom interactions between teacher and students and peers that gradually lead to an understanding and mastery of a written genre. It would be possible to add asynchronous and synchronous communication and/or email to the program during the laboratory report writing phase and this may well go some way towards addressing these issues but the richness of face-to-face communication and learning experiences cannot be replicated through this online program.

IMPLEMENTATION

In implementing the program the emphasis has been on integration as this is seen as critical for success in online learning [33]. In particular, the close alignment of assessment tasks with the program is an incentive for student usage. Key features of the implementation have included an introduction to the online program as part of the course introduction, the diagnostic and formative assessment of student report-writing skills at the beginning of the course and a staged approach to the writing of the assessed laboratory report. As part of the course introduction, students worked in groups on parts of the online writing program and then took part in a pre-test that used exercises from each part of the program. The purpose of the pre-test was to give staff information about, and to assess student baseline capabilities in particular features of the report writing genre such as structure, discourse and grammar. For students, the pre-test oriented them to the computer program and raised awareness of academic writing requirements in the report writing genre. Although student performance on the pre-test was recorded, these marks were not included in the overall assessment.

In addition, students undertook an extended writing task, a practice report in which they presented and wrote the results and discussion stages of a laboratory report based on processed data, a description of the materials, measurements and methods, together with an explanation of the underlying theory and its application to analysing the data. Aspects of the data analysis required from the students included the development of appropriate figures (graphs), appropriate layout and description of results and appropriate discussion of significance. Marks for both content and language were recorded as a baseline measurement of student literacy for the report writing genre and these were used in the overall assessment, although this practice report mark was awarded a considerably lower proportion of the overall mark. This exercise allowed students to practise writing in context and to combine their understanding of structure, discourse and language features to produce a complete text. In addition, students received formative feedback on both the content and language of their reports from subject area staff and language and learning staff. For staff, this provided an insight into student baseline capabilities in literacy for extended report writing and an opportunity to give students personal formative feedback on their strengths and weaknesses in report writing so as to improve outcomes for later reports. After this, students undertook laboratory work in groups and wrote individual draft reports for feedback. While writing their reports they were encouraged to consult the online program when necessary. They received feedback on their draft reports both through a template and also through individual comments from markers. They then had the opportunity to resubmit a final draft to gain a higher mark if they so desired.

EVALUATION

Our main purpose in evaluating the online program was to assess whether it had contributed to student learning of the laboratory report writing genre in chemical engineering and, if so, how this had come about. We were also interested in whether the program had contributed to improved student performance in laboratory report writing, both in terms of academic literacy and content, and whether there were differences in performance between native speakers and non-English speaking background students (42% of cohort, $n = 46$). Also, student opinions were sought on the content and design of the program, their learning experiences, choice of learner pathway and preferred method of learning about report writing.

Insights into student learning from the program were gained from open-ended questionnaire data and focus group interviews carried out at the end of the course. The aim of the questions was to encourage students to reflect on and articulate their conceptions of learning through writing (What has this online program taught you about writing in chemical engineering? What have you learned from the online program about why chemical engineers write laboratory reports and why they write reports in the way they do?) and their approaches to learning through the writing process (How did you go about writing your report using the online program and why did you go about it that way? What changes did you make?). Students were also encouraged to comment on affective issues, such as ease of writing and increased confidence. Changes in student performance were monitored using pre and post-test scores based on the same online multiple choice exercises from the

program and from marks awarded to students on their practice report, draft and final reports. In addition, an assessment of academic literacy in all three reports was carried out using the MASUS (Measuring the Academic Skills of University Students) instrument [34]. This provides a spectrum of perspectives on the students' writing from macro to micro level, in four areas, namely, transfer and integration of relevant reference material, use of an appropriate genre structure, academic style and cohesion, and correct grammar. Although the instrument is primarily a diagnostic tool, in this instance students were awarded marks for their achievements in all four areas. A closed-ended questionnaire, consisting largely of Likert rating scales, invited students to give their opinions on several characteristics of the program in four main areas, namely program design (e.g. colour, buttons etc.) instructions for the program (e.g. difficulty, effectiveness etc.), interacting with the program (e.g. learner pathways, usefulness of explanations, exercises, feedback etc.) and learning from the program (e.g. more aware of problem areas). Although report and literacy marks for 46 students who completed the course were recorded, only 22 students volunteered both pre- and post-test data and 26 students, questionnaire data.

EVALUATION OUTCOMES AND DISCUSSION

Student performance

Overall, the student report mark increased over the duration of the course from an average of 61.7% to 65.7% to 77.4% for the final report. The differences between the practice report and the final report, and the draft and final report, were significant at the $p < 0.05$ and $p < 0.01$ levels, respectively. However, the improvement in student performance is a result of all the teaching/learning activities over the whole course, not only the online program and, in particular, the individual feedback given to students on their draft report may have brought about the more significant changes. A clearer indication of the impact of the program can be gained from monitoring the changes in academic literacy measurements. However, the average literacy assessment actually decreased between the practice report and the draft report from 79.4% to 74.5% before rising again to 77.6% for the final report. The differences between the practice and draft report and draft and final report were significant at the $p < 0.05$ level. The decline in literacy between the practice and draft reports could be due to the challenge of writing a whole report compared with only part of a report where most of the data had been processed. In addition, since students also received individual feedback on their academic literacy after writing their draft report, this would also have contributed to improved literacy levels in the final report.

The most important indicator of the contribution of the online program to student performance is the pre- and post-test scores as these tests were based on the same extracts from the online program. The average score improved from 57.2% to 62.8% and this difference was found to be statistically significant at the $p < 0.01$ level. However, it must be noted that the sample of students doing both a pre- and post-test was small. Nevertheless, this is a good indication of the effectiveness of the program for this group of students. There were no significant differences between NSEB students and native speakers over all of the performance indicators.

Student evaluations

Student ratings in the areas of program design, instructions for the program, and interacting with the program are summarised in Fig. 3 below.

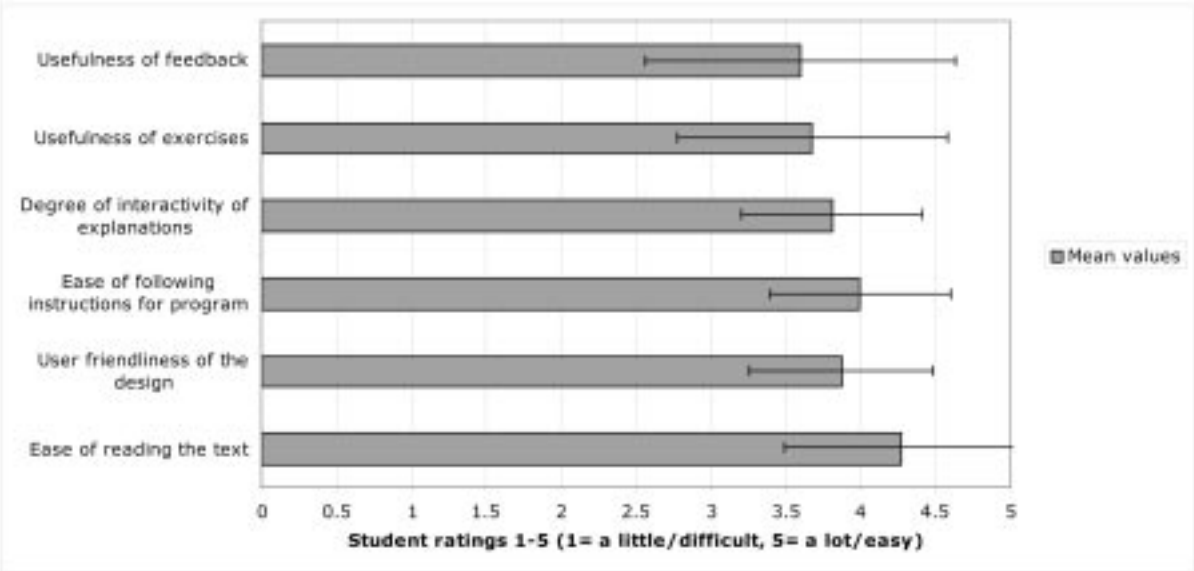

Fig. 3. Student evaluations of features of the program.

Overall, student evaluations were very positive. Ratings for ease of reading the on-screen text were surprisingly high as we had been concerned about text presentation given that a program on writing needs to use many authentic text-based examples for explanations and exercises. However ratings for the usefulness of the exercises were lower and this may indicate some dissatisfaction with the limited design of computer-based exercises for learning about writing. In addition, ratings for the usefulness of the feedback were also lower than expected, although in a subsequent question 90% of students responded that feedback helped them to understand where they went wrong and this was supported by focus group comments ('feedback was logical and it made sense'). Most students browsed the program for particular information before working through a section in detail. Almost two thirds of students requested more example texts and their preferred method of learning about report writing was a booklet (44%) rather than a computer-based program (32%), with the remainder (24%) preferring a workshop. However, focus group and open-ended comments suggest that students who preferred a booklet may well have been satisfied with some facility to print content and structure guidelines for each part of the report, which they could then refer to more easily while writing ('make parts of the program printable, then students can print out what they need, that involves students in the program—booklets tend to be ignored').

Student learning

In general, students rated the program highly in terms of all aspects of their learning (Fig. 4).

In particular, strong ratings were given for learning appropriate structure and content. However, learning about language and chemical engineering topics was rated less highly, although students were clearer about the purpose of reports in chemical engineering. In addition, although the majority was more aware of their problem areas, this did not seem to lead to increased confidence in report writing, which was rated less highly, only a third of respondents giving strong positive ratings in this area.

Open-ended data and focus groups provided more insight into how students learned from the program. In analysing the open-ended comments, a phenomenographic approach was used (ref) in which themes in student comments were categorised in terms of three descriptors, namely insightful, instrumental and mechanistic. An insightful conception or approach indicates a deeper learning experience where students show a more integrated and holistic understanding of both chemical engineering content and its communication. An instrumental conception and approach is one where students act more strategically and focus primarily on learning about how to produce a successful written text for assessment. Mechanistic conceptions or approaches are characterised by strict adherence to rules or guidelines with little indication of learning or understanding or in some cases student comments indicate an absence of learning.

Overall, these comments indicate that the majority of students had an instrumental conception and approach to the program, using it strategically to learn about laboratory report writing and the genre of the laboratory report in chemical engineering and very few students saw any connection between writing as a way of increasing understanding of chemical engineering. However, despite this, the majority of students had a very clear conception of the purpose of the laboratory report genre in chemical engineering and its place in the professional community they are about to join. Many students' comments covered both an

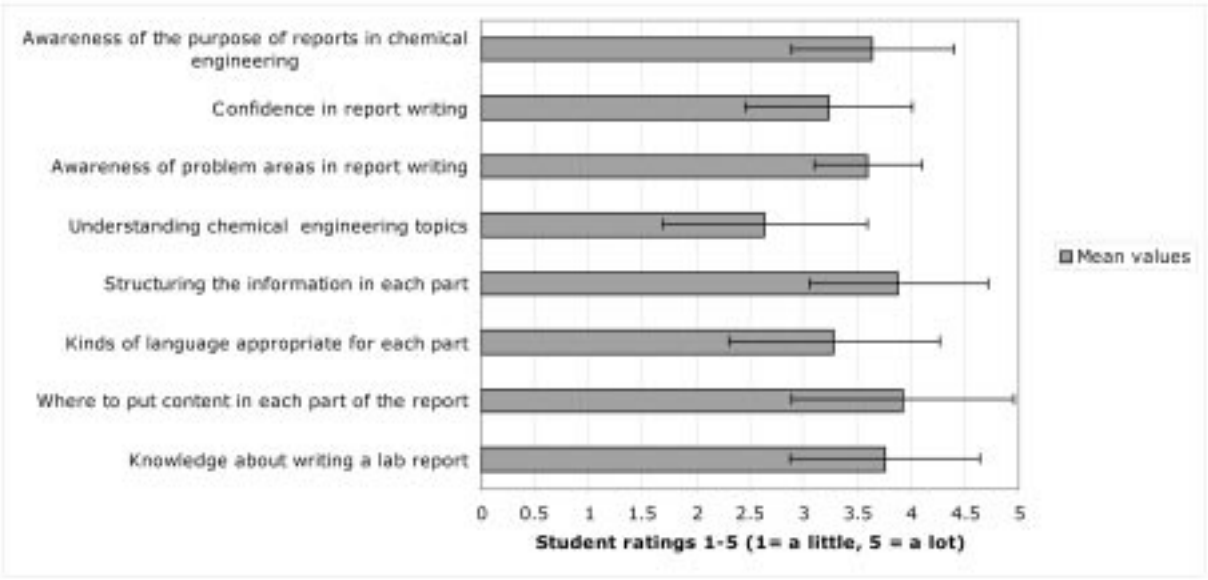

Fig. 4. Students' ratings of their learning from the program.

Table 1. Student conceptions of and approaches to writing using the online program

Conceptions of learning through writing				
What has this online program taught you about writing in chemical engineering?				
Insightful	Learning as understanding of chemical engineering through writing	'The program has taught me to ask myself why I got the results I got.'	No.	%
			6	27
Instrumental	Learning about the report writing genre in chemical engineering	'I learned how to structure the report, what types of information to put in the relevant sections.'	14	64
Mechanistic	Learning about the rules of writing	'Useful for grammar and sentence construction.'	2	9
What have you learned from the online program about why chemical engineers write laboratory reports and why they write reports in the way they do?				
Insightful	Learning about the purpose of the report genre in chemical engineering	'I learned that a chemical engineering report is written to enable the reader to firstly understand the theory behind the experiment and then explain the implications of the results.'	No.	%
			13	59
Instrumental	Learning about report writing as a means of conveying information	'The report is written so that it is easy to understand.'	3	14
Mechanistic	Learning nothing from the program	'I don't know, obviously not much.'	6	27
Approaches to learning through writing				
How did you go about writing your report using the online program and why did you go about it that way? What changes did you make?				
Insightful	Using the program to understand how chemical engineering knowledge is presented in a report	'I now place more emphasis on understanding what results mean rather than getting the results themselves.'	No.	%
			1	5
Instrumental	Using the program to evaluate report writing	'The report is more coherent, structured and well argued in comparison to previous reports.'	18	82
Mechanistic	Using the program to find the right answer	'I've improved my report by using the correct language.'	3	13

instrumental and mechanistic conception and approach and the latter category should not necessarily be seen in a negative way, as students in their third year already have some knowledge and experience of report writing in the discipline and may have merely used the program to check certain discrete aspects of the process and product, such as choice of tense or referencing conventions. In other words, students used the program according to their individual needs, which was, in fact, the overall aim of the program. There were no clear patterns between these three categories (insightful, instrumental and mechanistic) and performance, in contrast to much phenomenographic research [31].

Table 2. Students' affective responses to the online program

Has the program made report writing easier? Why? Why not? Do you feel more confident about report writing after using the program? Why? Why not?			
Positive	'The program has made report writing easier because it gives a solid structure.'	No.	%
		16	76
Mixed	'The program hasn't made report writing easier but it has given me a better idea of what to put in each section.'	3	14
Negative	'Actually I'm more confused now because I've been writing reports in a particular way for the past two years and now I'm not sure what the best way is – you should have this in the first year.'	2	10

This program was used by third year students who already have substantial knowledge of the field and its discourse conventions and this would inevitably influence the way they used and learned from the online program. It is possible that questions targeting all of the writing activities they engaged in throughout the course would have elicited more insightful comments indicating an understanding of engaging in writing to further their discipline knowledge.

The majority of students returned positive affective comments about the program and its value as seen in Table 2.

Focus group comments support these positive evaluations ('It's a great program' and 'I learned a lot' are typical student comments), particularly for learning about the structure of a report and the appropriate content for each stage. Specifically, students provided useful feedback on a number of aspects of the program, the exercises, the language sections, and the use of chemical engineering examples and they made recommendations for the wider use of the program and its closer integration into courses.

Comments on the exercises were mixed. Some exercises were described as tedious or too long although useful in some instances. However, other students wanted more exercises ('There are not too many exercises', 'The more the better', 'Students can decide for themselves whether they need to do them'). This suggests that overall there is a reasonable balance in the number and type of exercises offered. The language sections were particularly appreciated by NESB students who found them useful for seeing examples of appropriate language for report writing, but felt that the program needed a glossary/database for words/phrases, for example phrases for describing graphs in the text and they wanted more information about language use. ('The program guided me in areas . . . where I was really weak and most importantly, in the kind of language that's appropriate.') The chemical engineering content of the program was considered to be helpful ('It's good that the program uses chemical engineering content as it gives practical examples of what we have to write about.').

Students suggested emphasizing the generic elements of report writing, so that the program would be more useful in other contexts such as the earlier years of the undergraduate course ('The program should be promoted throughout the department—this is the best tool we have to help you write a lab report.'). Although they thought the program was well integrated into the course, they emphasized the need for even closer integration so that more students would use the program. Finally, students exhibited a growing understanding of the variety of report genres in chemical engineering and their different purposes and structures ('Other reports are required in the third year, e.g. design reports, professional reports, these need a different structure, I used the lab report structure and I was marked down. We need another program for professional report writing.'). Overall, it is worth noting that the mechanistic reactions in Table 1 and the negative reactions in Table 2 are a small minority of the overall responses.

CONCLUSIONS

Overall, the online laboratory report writing program has proved an effective learning initiative in the third year laboratory class in chemical engineering and this has already led to the development of new programs in second and third year biochemistry. Students who used the program perceived they had indeed learned from it, especially in terms of the generic structure of a laboratory report in chemical engineering and that it had contributed to improved performance in their laboratory report writing. Our quantitative data especially on the pre- and post-test marks tend to support this position. In addition, students used the program selectively, according to their individual needs and for the most part were satisfied with their interactions with the program in terms of explanations, exercises and feedback. However key issues remain. These include how to increase students' confidence in their writing, how to help students transfer and apply learning to new contexts and how to help students realise the connections between writing in their discipline and an improved understanding of content. The integration of a program like this or a more generic or simplified version into earlier years of the curriculum will be a first step towards developing confidence in writing over the undergraduate years as well as an appreciation of writing to learn. In addition, extending this online program to include other report genres would go some way to help students to see the similarities and differences between the different reports in their discourse community and transfer and adapt them to varying purposes and contexts. The provision of a facility for online discussion or email during the report writing process would also help to improve students' confidence in their report writing abilities, although this would require lecturer moderating time in order to be effective. This online program provides students with a valuable learning environment for the laboratory report genre in chemical engineering. However, the extent to which students will use and learn from the program will ultimately depend on their perception of its relevance to their learning goals. This in turn will be shaped by the place of the program within the overall teaching/learning context and particularly, in the case of report writing, within assessment practices.

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