Article

Enhancing the Communicative Competence of Science Undergraduates Through the Use of Popular Science: A Perspective From the Students

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ABSTRACT

Background: Universities increasingly recognise the need to teach communication skills. Various approaches are adopted to develop undergraduates' academic literacy skills, including a range of collaborative approaches.

Aim: This study traces the implementation of an initiative to enhance first year science undergraduates' effectiveness in science communication through the development of a new course SP1541/ES1541 "Exploring Science Communication through Popular Science".

Method: Mixed method approach of pre- and post-course perception survey, reflective letter analysis and covariate correlation analysis with perceived learning outcomes were performed to investigate impact indicators of the course.

Conclusion and implications: Pre-course analysis corroborates previously observed demographic trends and confirms diverse English language competency among students. Perception survey and reflective letter analysis suggest that these initiatives have been effective in improving the competency and confidence in students' academic literacy skills and shed light on preference of reading materials. Covariate correlation analysis further illuminates underlying differences in perceived learning outcomes among male and female undergraduates, grade obtained for the GCE A-level General Paper (English language), home language, declared science subject major, and the semester when the course was read. This study contributes towards augmenting our appreciation of the epistemologies in the teaching and learning of communication within a multi-racial context and informs English language educators on the potential benefits of personalising the instructional design of a communication course for science freshmen. In conclusion, the collaboration between language and disciplinary experts in planning the science communication curriculum impacts perceptive learning outcomes positively.

KEYWORDS

Course design; learning outcomes; perception survey; popular science books; science communication

INTRODUCTION

The rigorous nature of academic writing and the need for strong communicative competence amongst undergraduates has been widely discussed. The sentiment of a lack of necessary communicative competency is best underscored by Bok (2006) who commented on largely native speakers of the language. Citing Richard Light's interviews with 1,600 undergraduates, Bok highlights that respondents cited the need to improve their writing three times more frequently than other educational outcomes. Mercer-Mapstone and Kuchel (2015) commented on the Australian science undergraduate programmes' inadequacy in preparing students in the communication learning outcome as it was described as 'underdeveloped' by graduates, professionals and employers. Mercer-Mapstone and Matthews (2017) point to the lack of training in oral, interpersonal and written skills in science undergraduate communication initiatives although these programmes are effective in teaching analytical, problem solving and technical skills in the learning of scientific knowledge.

In the context of a science undergraduate programme where this study is situated, the need for strong communication skills is well recognized. Considering the importance of developing writing and communication skills in the early stages of students' academic paths, the incorporation of a communication course for freshmen in the Faculty of Science becomes pertinent. In the current context of English medium universities, it is commonplace to find undergraduates whose first language is not English. Murray and Nallaya (2016, p. 1) describe the possible demography of university students where "...a proportion have neither the language proficiency necessary to successfully negotiate the demands of their study programmes nor sufficient conversancy in the literacies required to experience successful learning." Additionally, the communication of science is a negotiation process with implications for how meaning is made and how identity is shaped as the nature of scientific knowledge is contested. As such, there was an impetus for collaboration between the writing specialists and science faculties in our university to co-develop a new science writing course. The course encompasses the development of all science first-year undergraduates' communicative competence in a compulsory course which introduces students to academic literacies essential to the construction of meaning for academic purposes. It enables students to read science-related publications critically, and to articulate scientific arguments and perspectives coherently both in writing and orally. Learning such academic literacy skills involves what Hathaway (2015) describes as the epistemological, cultural and linguistic aspects as undergraduates learn to participate in new knowledge communities, each having their conventional ways of constructing and expressing knowledge and meaning.

Furthermore, effort to shape curriculum development needs to be informed by investigations into baseline evidence of course effectiveness in the evaluation process. Such investigations attunes to Hutching's "what works?" question to gain insights into the effectiveness of the course and to inform further communication curriculum development. Students' perspectives, which is the focus in this paper, would provide insights into students' experience in the learning of communication skills within their degree programme. Using the Science Student Skills Inventory as a tool, investigations into student perceptions of science communication courses in the Australian setting have provided insights on the effectiveness of these courses with reference to stated graduate learning outcomes (Mercer-Mapstone & Matthews, 2017). Thompson, Eodice, and Tran (2015) defend the need for investigating student perception in reforming General Education programmes as students have become "the most neglected audience among the various participants in general education" (p. 279). In the context of General Education programme evaluation, Thompson, Eodice, and Tran (2015) point out that engagement with student perceptions has exposed the disconcerting sentiment on student experience - that higher education is a process that has to be gotten through with as efficiently as possible. Such insights present an example of evaluation that contribute another perspective to help educators rethink the intent and actual impact of the many well intentioned curricular changes that may not necessarily achieve the intended outcomes. It is in these dual contexts of developing students' communicative competence and investigating their perception that we aimed to examine the degree of effectiveness of the course as perceived by the students.

Additionally, there exists several contextual and anecdotal perceptions in terms of language abilities among science undergraduates. For instance, female students are better in language skills than male students, and Life Sciences majors tend to be stronger in writing and communication skills as compared to their Mathematics and Physics counterparts. One of the research aims was to investigate if there are substantial differences in perceived learning outcomes among freshmen of different gender, grade obtained for the General Certificate of Education Advanced Level (GCE A-level) General Paper (GP) in English language, home language (English versus mother tongue languages such as Mandarin, Malay and Tamil or local dialects), declared major (one of the seven majors) and semester where the course was read (Semester 1 versus Semester 2).

In summary, this study adopted a mixed method approach (Yin, 2009) to address three research questions within a case study setting. The questions are: (1) How do students perceive the impact of the course in achieving the intended learning outcomes? (2) What are the underlying preferences and trends for the popular science books? (3) How do students of different gender, declared major, home language, registered semester and GP grade differ in their performance and perception of course effectiveness?

Design of the module

The course draws from the Academic Literacies approach (Lea, 2004) which prioritises the learning of a new academic culture in the process of learning to write at the academy. It is more about learning to negotiate meaning in the context of a community of users as well as developing an identity in the process, rather than learning to write in a right way from a learners' deficit point of reference. The approach emphasises the need for students to engage with the process of writing, to explore, dialogue, reflect and actively develop a sense of identity and voice in relation to the texts being written.

The design of the module also draws on articulations of outcomes in higher education assurance documents that are relevant to the tertiary science education scene in this context. For instance, the Quality Assurance Agency for Higher Education (QAA) pertinent to the British setting (QAA, 2008) stipulates the need for bioscience graduates to "engage in debate and dialogue both with specialists and non-specialists, using appropriate scientific language". Also a good grasp of subject knowledge and "engagement with some of the current developments in the biosciences and their applications, and the philosophical and ethical issues involved" was another guiding outcome expected. These detailed statements of learning outcomes, though specific to the area of bioscience and to the British context have significance for the general tertiary science education context as any graduate should be expected to demonstrate that engagement with conversations on respective philosophical, conceptual and application issues. Also, learning outcomes draw on relevant science communication literature, which provide some insights on outcomes necessary for the effective communication of scientific knowledge. Mercer-Mapstone and Kuchel (2015) outline 12 core skills for effective science communication and suggest two key skills for prioritisation namely, (1) to identify and understand a suitable target audience and (2) to use language that is appropriate for the target audience. Essentially, these two skills, though highly prioritised as effective science communication skills are also important generic skills in developing academic literacy as knowing the audience and presenting knowledge using the appropriate register of language for the academic audience are fundamentals in effective communication. As such, one important aspect of communicating science is the need for the generic skills of coherence and clarity, especially in situations where engagement with the lay audience is concerned.

Guided by these articulations of learning outcomes, this outcome-based course enables students to have (1) developed the habit of reading, especially in science-related topics, (2) enhanced their ability to critically question published scientific information, (3) enhanced their ability to articulate opinions and perspectives and (4) developed coherence in their writing and oral communication at the completion of the course.

One distinctive feature of the course is the use of the content of popular science books to engage students' reading, thinking, speaking and writing skills. The embedding of academic literacy skills takes the form of student engagement with science related texts and topics. As pointed out by Afonso and Gilbert (2013), popular chemistry science texts enable the informal engagement of chemistry knowledge where the focus on abstract concepts that are detached from technological applications and implications is minimized. Engagement with these materials might present the students with rich examples of the essentials of good communication of science–of how science can be presented to facilitate the informal acquisition of scientific knowledge and thus, science education. Parkinson and Adendorff (2004) recommend the use of popular science articles for teaching scientific literacy, although they identified clear differences between the popular science genre and the research article and textbook genres which are more similar to each other. One major difference between popular science and the research article and textbook genres is the way in which knowledge is presented as provisional rather than as facts accepted by the scientific community. As explained by Parkinson and Adendorff (2004), the narrative nature of popular science depicts knowledge as yet to be endorsed claims attributable to research results in a genre that is high on the interpersonal scale and prioritises what people think, say and feel about these knowledge claims. It is common to find information in popular science genres configured as a debate between two opposing voices and not couched as established knowledge claims. This feature facilitates the reading, thinking and critical response to knowledge presented in the current module; in fact, the discursive nature of these texts is leveraged on to generate the necessary discussion and analysis of targeted notions to enable further written responses to these claims that come across as provisional.

Norris, Phillips, and Korpan (2003) highlight the beyond school texts genre such as the Internet and other popular media, including popular science texts as important avenues for the learning of scientific text interpretations. These researchers investigated into various aspects of how students engage with "pragmatic meaning of the reports that pertained to the goals of the authors and the context of language use" (p. 124). The interplay of language and scientific concepts contributes to the level of reading difficulty in such genres. Norris, Phillips, and Korpan (2003) found that amongst their undergraduate participants, only 5% reported that the media reports were very difficult to read. The main reason given for the difficulty level was unfamiliarity with the topic in the media reports. Thus, the selection of popular science texts in this study was guided by the considerations of students' topics of interest as well as the difficulty level of the language used, although based on Norris, Phillips, and Korpan's findings, difficulty level was not perceived to be too high among their respondents.

The five popular science books ascribed to the course were carefully selected by members of the Science Faculty Curriculum Committee and English language educators. The books belonging to the five domain areas of Physics, Life Sciences, Mathematics, Chemistry and Statistics are namely (i) *A Brief History of Time*, (ii) *Food Inc.: Mendel to Monsanto-The Promises and Perils of the Biotech Harvest*, (iii) *The Music of the Primes: Searching to Solve the Greatest Mystery in Mathematics*, (iv) *Napoleon's Buttons: How 17 Molecules Changed History*, and (v) *Statistics—A Guide to the Unknown*. The course content revolves around controversial issues raised in each of the popular science texts which present the springboard for small group discussion pedagogy. One of the aims was to investigate the degree of students' engagement with the content of popular science books by surveying their underlying reading preferences and trends.

The 48-hour course is taught over 13 weeks with two 2-hour sectional teachings per week. The academic literacies approach emphasises the need for students to engage with the process of writing, to explore, dialogue, reflect and actively develop a sense of identity and voice in relation to the texts being written. As such, the relatively small class size of up to 18 students per class is necessary for a process writing approach where student-tutor consultation is worked into the schedule to discuss writing drafts at different stages of the process.

In terms of course content, controversial issues raised in each of the popular science texts present the springboard for a small group discussion pedagogy. This is similar to the embedding of multiple academic literacies in a Science, Technology, Engineering, and Mathematics (STEM) curricular (Soules, Nielsen, LeDuc, Inouye, Singley, Wildy, & Seitz, 2014) where reading and writing literacies form an important component of the programme The authors explain the importance of effective reading strategies for texts with higher difficulty levels to be developed amongst students who may have mastered basic reading skills. Soules *et. al* (2014) highlight the active nature of reading that involves the construction of meaning before, during and after reading science texts, on the basis of Sweet's (2000) work. The awareness of the use of metacognitive strategies including the activation of schematic knowledge to construct new meaning and to connect known and new knowledge all contribute to the reading comprehension process. Writing competence would then entail the teaching of effective reading skills to construct relevant scientific knowledge. These interlocking process of reading, critical thinking strategies, the construction of meaning and the connection of knowledge are metacognitive skills which help students learn successfully in a college physics class (Bullock, 2006). Table 1 presents a sample of the course organisation that connects classroom content, pedagogy and learning outcomes.

Table 1
Course organisation that connects classroom content, pedagogy and learning outcome

Pedagogic Content	Pedagogic Approach	Learning Outcomes
The Selfish Gene (pp. 2, 12 -20) 1. Ideas from book: e.g. the 'survival of the stable' as the basis for evolution 2. Organising principles in the structure of an argument: credibility of grounds 3. Language skills: conciseness	Small group discussion: 1. Classroom activities: summary of reasons for and against controversy; Synthesis of credible grounds for and against the controversy; iterative representation of synthesis with the aim of optimising conciseness 2. Task: individual synthesis of controversy with an opinion of the credibility of main grounds identified	1. To enhance their ability to critically question published scientific information. 2. To enhance their ability to articulate opinions and perspectives. 3. To develop coherence in their writing and oral communication.

Students are graded based on 100% continuous assessment with six components (Table 2). The summative assessment (Item 3 "Argumentative Essay") which bears the heaviest weightage (30%) draws together various skills sets of reading, thinking, arguing and writing taught in the course with an emphasis on showcasing the acquired principles of effective written communication.

Table 2
Components of continuous assessment

Assignments	***Weightage***	
1. Synthesis writing (500 - 600 words)	10%	
2. Group Presentation	15 %	
3. Argumentative Essay (1500- 1800 words)	30%	Draft 1 (0%) Draft 2 (20%) Final Draft (10%)
4. Peer Review Report	6%	
5. Individual Oral Presentation	20%	
6. Reflection	9%	
7. Class Participation: discussion (group and online discussion), feedback, e-tutorial participation	10%	

METHODS

Study subjects and pre-course survey

Based on the pre-university credentials, the freshmen are broadly categorized into high school graduates who sat for the GCE A-level, International Baccalaureate, High School Diploma, Polytechnic Diploma and foreign-equivalent examinations. Taking into consideration the limited sample size from the other four groups of students, this study focused on the GCE A-Level freshmen who represent the majority of the student population. The pre-course survey conducted during Week 1 captured the background of students with respect to their self-rated writing and communication skills level so as to establish the baseline for a valid longitudinal assessment of the perceived learning outcomes at the end of each semester. Students' demographic profile and pre-university English language competency (based on home language, GP grade, and self-rated writing and communication skills level) were systematically analysed. For the pre-course survey, the response rate was measured, and students were surveyed based on their attitudes towards formal writing, self-appraisal of their writing competency and oral communication skill, and finally their confidence in writing.

Post-course survey

In addition to the pre-course survey, a post-course survey was administered in Week 13 where students were asked to rate the different learning outcomes. The questions were designed such that answers from pre- and post-course surveys could be correlated to draw meaningful interpretations of the perceived learning outcomes and in turn address Research Questions 1 and 2 by evaluating their perceived effectiveness of the course and preferences for the popular science books. With students' baseline self-rated writing ability and oral communication skills, we matched the students' self-rated improvement to their self-perceived need for improvement. Based on the mapping algorithm, we constructed the perceived learning outcomes where we categorized the students into "exceeding target" (where students' perceived improvement in skill is more than what they felt they needed), "on target" (where students' perceived improvement in skill is comparable to the level they felt they needed) and "below target" (where students failed to improve as much as they felt they needed).

Text analysis of reflective letters

Within the scope of the course, students are required to write a reflection via a letter explaining how the course and the assignments have helped them develop as a reader, writer and communicator, and discussing their strengths and weaknesses and the challenges faced in completing the assignments

(Table 2). The analysis of the reflected letters provided further qualitative data to address Research Question 1. The reflective letters were compiled and processed using *IBM SPSS Text Analytics for Surveys 4* for the identification and categorization of specific opinions associated with the students' responses. The categories of interest include "module", "presentation", "summary", "essay", "discussion" and "peer review" that broadly categorized opinions provided on the course and its various assessment and classroom activities. The term "module" is used interchangeably with "course" in our university. Each category of interest comprised a list of keywords. For example, within the category "module", keywords such as "course", "module" and "module code" were included. These keywords were flagged when a student wrote them within the reflective letter, and tagged subsequently to a positive or negative opinion. An in-house dictionary of positive and negative opinions was built and categorized systematically. The software facilitated extraction of opinions even when multiple categories of interest were mentioned within the same sentence. For instance, if a student wrote "The module is fun but the summary writing can be tedious at times", the software will group "module" with "fun" and "summary" with "tedious", resulting in a positive opinion for the course and a negative opinion for summary writing. Nonetheless, the method of extraction was not fully dichotomous. For instance, a student who was not flagged for a positive opinion associated with a category does not imply a negative opinion towards that category. On the other hand, it was possible for a student to write both positive and negative opinions within the same category. Finally, a student might also not write on a specific category of interest.

Analysis of factors influencing perceived differential impact

To address Research Question 3, we investigated the perceived differential impact of the course among students of different gender, declared major, home language, GP grade and registered semester. The four key impacts were namely grade (*Impact 1*), self-reported improvement in writing ability (*Impact 2*) and oral communication skill (*Impact 3*), and confidence in both writing and communication (*Impact 4*). *Impact 1* was coded as an ordinal variable while *Impacts 2-4* were coded as binary variables. For the ordinal variable, a statistical analysis was performed using a cumulative logits model. For binary variables, a logistic regression model was fitted. For each impact, five variables namely gender, declared major, home language, GP grade and registered semester for the course were applied in the regression. In addition, students' responses in the pre-course survey and grades were adjusted where appropriate. Details of sub-population analyses are elaborated in the findings. All analyses were performed using software R version 3.2.0 using functions glm and vglm.

FINDINGS

Demographic profile and pre-course survey

The course was subscribed by 757 science freshmen (427 and 330 in Semester 1 and 2 respectively) where 650 GCE A-level freshmen (86%) were selected as our study subjects. Four main covariates were identified namely gender, declared major, home language and GP grade (Table 3). Computational Biology was not analysed due to negligible cohort size. Pearson's Chi-square tests revealed differences in the distribution of some covariates across the two semesters. Overall, the gender ratio of female to male students was about 2 to 1. There was higher proportion of female students in Semester 1 (p-value 0.065). There was no statistically significant difference in composition of majors between the two semesters (p-value 0.15). Life Sciences was the single largest major in the faculty (45.5%).

Around half of the freshmen cohort (50.5%) use English predominantly at home. There was a higher proportion of students who use English predominantly at home in Semester 1 (p-value 0.096). Between the two semesters, students from Semester 1 demonstrated better GP grades (p-value < 0.0001). Combining both semesters,13.9% of the students scored grade A for GP, 76% scored grades B-D while 10.2% obtained a marginal pass or failed the GP examination.

The response rates for pre-course survey were more than 99% in both semesters. Combining both semesters, 62% of the responders were neutral about formal writing while 23% and 15% were fearful and enjoyed writing respectively. 58% and 26% of the freshmen indicated that they needed some and significant improvement in writing respectively while 16% expressed that they required little or no improvement in writing. A large percentage of students (81%) indicated that they were either relatively or very confident in daily writing while the remaining 19% were not confident. Finally, 53% and 24% of the freshmen indicated that they needed some and significant improvement in oral communication skill respectively while 23% expressed that they required little or no improvement in communication.

Post-course survey

For the post-course survey, the response rates were 94% and 98% in Semesters 1 and 2 respectively. In the post-course survey, students were asked the question "Do you think your writing ability has improved after reading this course?" and they could choose to answer "Yes, it has improved significantly", "Yes, it has improved slightly" and "No, it has not improved at all". A similar question was asked with regards to oral communication skills. The general

distribution pattern of responses was comparable between the two semesters (Figure 1). In terms of writing ability, 21% and 75% of students perceived that their writing ability had improved significantly and slightly, respectively. A similar positive trend was noted for the improvement in oral communication skill (Figure 1). In both pre- and post-course surveys, students were also asked to rate how confident they feel about writing in daily life with three choices: "very confident", "relatively confident" and "not confident at all". Overall, from pre- to post-course surveys, there was an approximate 2.5-fold increase in the number of students feeling very confident about writing while the percentage of students feeling not confident at all fell by 58% (Figure 1).

Table 3

Demography of GCE A-level freshmen

		Academic Year 2013-2014		***Semester 1***		***Semester 2***	
Gender	Female	428	65.8%	269	68.6%	159	61.6%
	Male	222	34.2%	123	31.4%	99	38.4%
Major	Chemistry	128	19.7%	76	19.4%	52	20.2%
	Computational Biology	1	0.2%	1	0.3%	0	0.0%
	Food Science & Technology	29	4.5%	22	5.6%	7	2.7%
	Life Sciences	295	45.4%	171	43.6%	124	48.1%
	Mathematics	83	12.8%	58	14.8%	25	9.7%
	Physics	38	5.8%	22	5.6%	16	6.2%
	Statistics	76	11.7%	42	10.7%	34	13.2%
Predominant language use with family[ǂ]	English	315	50.5%	196	53.4%	119	46.3%
	Non-English	309	49.5%	171	46.6%	138	53.7%
General Paper grade[∞]	A	90	13.9%	65	16.6%	25	9.7%
	B	234	36.1%	161	41.2%	73	28.3%
	C	176	27.1%	121	30.9%	55	21.3%
	D	83	12.8%	27	6.9%	56	21.7%
	ESU[#]	66	10.2%	17	4.3%	49	19.0%

#Grades E, S and U were collated. Grade 'E' denotes pass. Grades 'S' and 'Ungraded or U' indicate that the candidate failed to obtain a pass in the General Paper. 26 and 1 missing data points were noted for ǂ and ∞ respectively.

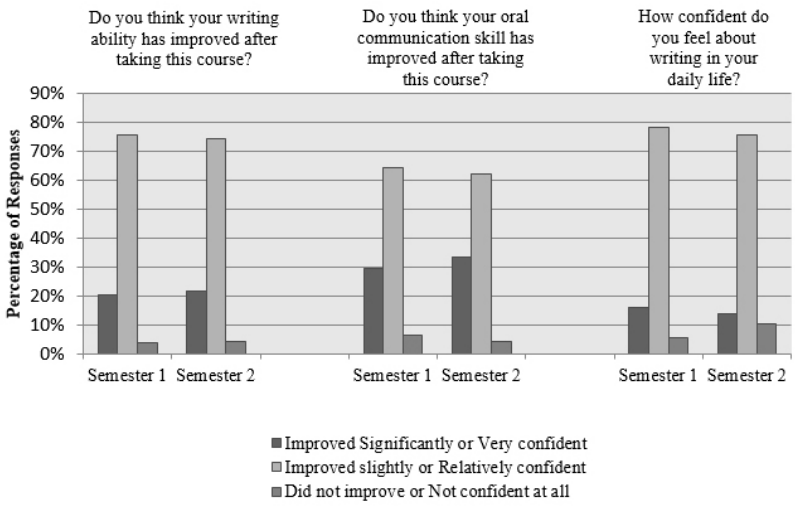

Figure 1. Distribution pattern of responses to questions posed during post-course survey on improvement in writing ability, oral communication skill and confidence in writing.

With students' baseline self-rated writing ability and oral communication skills, we matched the students' self-rated improvement to their self-perceived need for improvement where we categorized the students into "exceeding target" (where students' perceived improvement in skill is more than what they felt they needed), "on target" (where students' perceived improvement in skill is comparable to the level they felt they needed) and "below target" (where students failed to improve as much as they felt they needed) (Figure 2). It was found that 28% of students exceeded their target in improving writing ability while 49% of students were on target. The majority of the students who failed to reach their targets are students who felt that that they needed significant improvement but only improved slightly after the course. In terms of oral communication skills, 37% of students exceeded their target while 44% were able to achieve their target. Finally, we determined that 26% of students improved in self-rated confidence towards writing while 67% of students maintained their self-rated confidence.

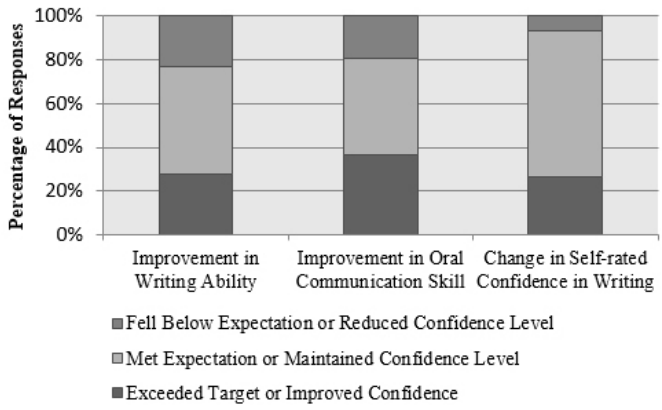

Figure 2. Percentages of students exceeding, meeting and falling below expectation with regards to improvement in writing ability, oral communication skill and confidence in writing.

Text analysis of reflective letters

Using the described methodology, we extracted opinions related to each category of interest. For the category "module", we gathered 479 and 175 entries associated with positive and negative opinions, respectively. For each category of interest, we processed the opinions in a similar fashion by classifying them into either positive or negative opinions (Figure 3). "Total Match" indicates the total number of students who expressed an opinion (positive or negative). 511 students (78.6%) expressed sentiments for the course and of which, 479 (93.7%) were positive opinions. Among the positive opinions, a majority of the students (404) described the course to be enjoyable and beneficial in terms of developing their communication skills. Among the negative opinions, 33 students felt the workload of the course was heavy. In terms of class activities, presentation received the largest numbers of opinions (358). Among those who expressed positive opinions towards presentation, 54 freshmen find presentation beneficial in improving their oral presentation skills and confidence. We further attempted to correlate the students' opinions towards the course based on their final grades. Interestingly, it was observed that there was a gradual increase in the proportion of students of a better grade expressing both positive opinions and negative opinions about the course.

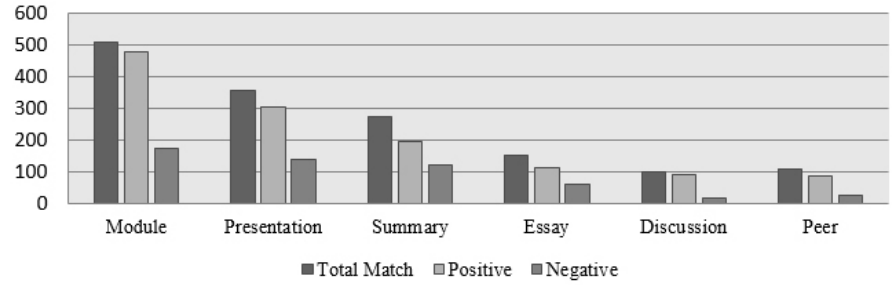

Figure 3. Total match, positive opinion and negative opinion expressed towards six categories of interest namely module, presentation, summary writing, essay writing, class discussion and peer review.

Popular science books

In the post-course survey, the freshmen were also asked which compulsory popular science books they enjoyed and would want to continue reading beyond the selected chapters discussed within the course. We observed a distinct pattern in the preference of popular science readings among science freshmen (Figure 4). The book that the students responded most positively to corresponds to their academic discipline. For example, Physics students tend to prefer the Physics book (*A Brief History of Time*) whereas Mathematics students tend to prefer the Mathematics book (*The Music of the Primes*). Some of these preferences extend across majors but the inter-major preference extension was not reciprocated. In particular, we noted that Life Sciences students prefer the Chemistry book (*Napoleon's Buttons*). However, this was not reciprocated by Chemistry students as a low overall preference level was observed among Chemistry students for the Life Sciences book (*Food Inc.*). A comparable relationship between the Mathematics and Statistics freshmen with regards to their domain-specific books was observed.

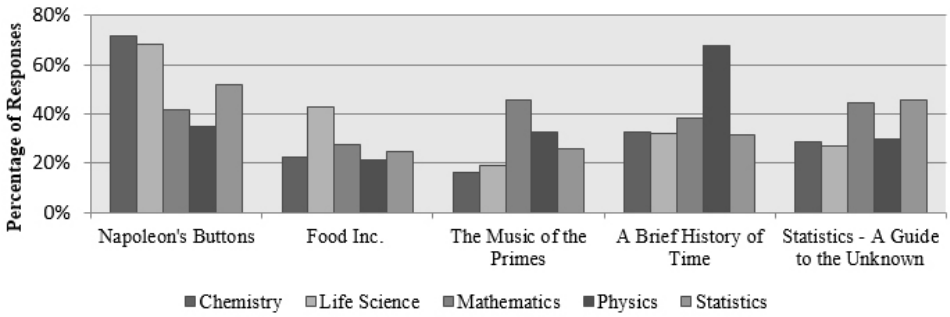

Figure 4. Preference of popular science readings among science freshmen. Each student could choose more than one book that he or she prefers to read.

Association of covariates with impact indicators

Grade. The grading of the course was based on 100% continuous assessment as summarized in Table 2. The grades achieved by the students provided a measure of their acquired competency in scientific writing and communication as evaluated by the instructors. The grades were grouped into three categories namely A- and above, B+, and B and below. A cumulative logit model was adopted and based on likelihood ratio test result, a simple proportional odds model sufficed. Table [4] summarizes the results of the regression. A negative coefficient is interpreted as less-likely associated with a better grade.

Regression (1) in Table 4 yielded the regression results based on all study subjects. In Regression (2)–(4), we divided the freshmen according to their registered semester and home language to further examine any underlying correlations. Controlling for all other factors, we observed that female students were statistically less likely to receive a higher grade compared to male students. Such correlation persisted across all sub-populations. Students from Chemistry and Food, Science and Technology majors were not statistically different from Life Sciences students in terms of grades. However, Mathematics, Physics and Statistics freshmen were found to be statistically less likely to score higher grades when compared to Life Sciences students. It was also noted the effect of declared majors on students' performance was more pronounced in Semester 1 versus Semester 2.

We also investigated the correlation between pre-university English language competency (GP grade) and their performance in the new course (grade). Controlling for all other variables, it was determined that students with poor GP grades were less likely to score better grades in the course. Moreover, the association between GP grade and course grade was more pronounced

among students who do not use English at home than students who use English at home [regressions (4) and (5) in Table 4]. Students who subscribed for the course in Semester 1 demonstrated better GP grades as compared to Semester 2 (p-value < 0.0001). In addition, students were more likely to receive a lower grade in Semester 2, even after accounting for differences in gender, declared major, home language and GP grade.

Self-reported improvement in writing ability and oral communication skill. In addition to monitoring the course grade, we investigated the difference in students' perceived learning outcomes among the different subgroups based on the responses given to the two questions in the post-course survey.

1. Do you think your writing ability has improved after reading this course?
2. Do you think your oral communication skill has improved after reading this course?

The responses were coded as "1" if student responded "yes, it has improved significantly" and "0" if the student responded "yes, it has improved slightly" or "no, it has not improved at all" In addition to the covariates shown in Table 4, we further controlled for students' self-rated ability in writing and oral communication skill in the pre-course survey where students were asked to rate their writing ability and oral communication skill as "needs no improvement", "needs a little improvement", "needs some improvements" or "needs significant improvement". Contrary to course grade, students' self-reported improvement in writing and oral communication skills was found not to be associated with any covariates, including students' own assessment at the beginning of the course (Table 5).

Table 4

Association between covariates and grade obtained for the course

			Sub-populations			
		Entire year	By semester		Predominant language with family	
		(1)	(2)	(3)	(4)	(5)
	Variable		Sem 1	Sem 2	English	Non-english
Major (Omitted: Life Science)	Female	-0.95***	-0.89***	-1.06***	-0.85***	-1.13***
		(0.18)	(0.24)	(0.27)	(0.24)	(0.26)
	Chemistry	0.09	0.41	-0.32	-0.26	0.5
		(0.21)	(0.29)	(0.32)	(0.29)	(0.32)
	Food Science & Technology	-0.06	-0.18	0.31	-0.4	0.34
		(0.39)	(0.46)	(0.75)	(0.57)	(0.55)
	Mathematics	-0.83***	-0.81**	-0.91*	-0.95**	-0.7^
		(0.25)	(0.31)	(0.43)	(0.35)	(0.36)
	Physics	-0.84*	-1.07*	-0.43	-0.76	-0.83^
		(0.36)	(0.48)	(0.55)	(0.54)	(0.5)
	Statistics	-0.56*	-0.64^	-0.53	-1*	-0.23
		(0.27)	(0.36)	(0.4)	(0.45)	(0.34)
GP grade (Omitted: A)	GP-B	-0.54*	-0.6^	-0.33	-0.28	-1.01*
		(0.26)	(0.31)	(0.46)	(0.33)	(0.41)
	GP-C	-0.84**	-0.85**	-0.75	-0.54	-1.4**
		(0.27)	(0.33)	(0.47)	(0.36)	(0.43)
	GP-DESU	-1.11***	-1.2**	-0.87^	-0.41	-1.94***
		(0.29)	(0.41)	(0.46)	(0.4)	(0.45)
	Predominant language used with family is not English	-0.1	-0.15	0		
		(0.16)	(0.21)	(0.25)		
	Semester 2	-0.71***			-0.82***	-0.61*
		(0.17)			(0.24)	(0.25)
	Sample Size	620	365	255	314	306

Standard error in brackets

***, **, * and ^ indicate statistical significance at 0.1%, 1%, 5% and 10% respectively.

Table 5

Association between covariates and self-rated improvement during post-course survey

		(Self-reported) significant improvement in	
		(1)	(2)
	Response Variable	Writing ability	Oral communication skill
Major (Omitted: Life Science)	Female	0.27	-0.01
		(0.22)	(0.2)
	Chemistry	0.18	-0.09
		(0.27)	(0.24)
	Food Science & Technology	-0.74	0.34
		(0.64)	(0.42)
	Mathematics	0.36	-0.65*
		(0.3)	(0.32)
	Physics	0.35	0.65^
		(0.45)	(0.38)
	Statistics	-0.04	-0.04
		(0.35)	(0.3)
GP grade (Omitted: A)	GP-B	0.49	0.1
		(0.35)	(0.28)
	GP-C	0.38	-0.25
		(0.38)	(0.31)
	GP-DESU	0.77^	0.22
		(0.4)	(0.32)
	Predominant language used with family is not English	-0.18	-0.03
		(0.21)	(0.18)
	Semester 2	-0.02	0.12
		(0.22)	(0.19)
Self-rate ability in pre-course survey (Omitted: Needs no or a little improvement)	Needs some improvement	-0.15	-0.01
		(0.28)	(0.23)
	Needs significant improvement	-0.44	0.08
		(0.34)	(0.26)
	Sample Size	612	613

Standard error in brackets

***, **, * and ^ indicate statistical significance at 0.1%, 1%, 5% and 10% respectively.

Self-reported confidence in writing. When the students were asked "How confident do you feel about writing in your daily life?", their responses were either "I feel very confident about writing", "I am relatively confident about writing" and "I am not confident about writing at all". Due to the small number of students who selected the third option, the outcomes were dichotomized as "1" if the students were very confident about writing and "0" if otherwise. Controlling for the students' self-reported confidence in the pre-course survey, course grades and other factors; we examined the effects of various variables on students' self-reported confidence at the end of the course (Table 6). While students' course grades were found previously to be associated with gender and declared major, similar relationship was not observed in terms of students' self-reported confidence. Similarly, students in Semester 2 were not less likely to report that they were confident about writing at the end of the semester.

On the other hand, unlike self-reported improvement in writing and oral communication that was not associated with students' responses in pre-course survey, students' self-reported confidence in post-course survey was found to be strongly associated with their self-reported confidence at the beginning of the semester. Those who indicated that they were not confident in writing during the pre-course survey were much less likely to become very confident about writing at the end of the course. In addition, while home language was not associated with course grade, it was significantly correlated with self-reported confidence. Those who did not speak English predominantly at home were less likely to report confidence in their writing. Likewise, GP grade was also significantly and positively associated with self-reported confidence, even after accounting for course grade (Table 6, Column 2).

Table 6

Association between covariates and self-reported confidence during post-course survey

	Variable	(1)	(2)
Major (Omitted: Life Science)	Female	-0.54*	-0.38
		(0.25)	(0.26)
	Chemistry	-0.01	-0.04
		(0.34)	(0.34)
	Food Science & Technology	-0.26	-0.29
		(0.68)	(0.69)
	Mathematics	0.11	0.22
		(0.37)	(0.38)
	Physics	-0.3	-0.2
		(0.53)	(0.53)
	Statistics	0.09	0.2
		(0.46)	(0.47)
GP grade (Omitted: A for GP)	GP-B	-1.28***	-1.26***
		(0.31)	(0.31)
	GP-C	-1.69***	-1.6***
		(0.36)	(0.37)
	GP-DESU	-1.77***	-1.68***
		(0.42)	(0.43)
	Predominant language used with family is not English	-0.63*	-0.6*
		(0.26)	(0.26)
	Semester 2	0.33	0.42
		(0.26)	(0.27)
Pre-course: How confident do you feel about writing in your daily life?	Not Confident	-2.1**	-2.07**
		(0.73)	(0.73)
Course Grade (Omitted: A/A-)	B+		-0.73**
			(0.28)
	B or below		-0.54
			(0.39)
	Sample Size	613	613

Standard error in brackets

***, **, * and ^ indicate statistical significance at 0.1%, 1%, 5% and 10% respectively

DISCUSSION

In this study, we conducted systematic research to investigate (1) the degree of effectiveness of the course as perceived by the students, (2) their preferences for popular science books and (3) the effects of gender, GP grade, home language, declared major and semester where the course was enrolled, on the learning outcomes.

The distribution of gender and majors was reflective of the general student distribution pattern where we typically observed two-fold as many female students as male students in the faculty and the largest admission of freshmen into the Life Sciences followed by Chemistry majors. Serendipitously, it also follows an observed trend in science communication electives where such course options are female dominated (Metcalfe & Gasgoine, 2004).

Tang (2015) suggests that to enable students' science communication skills, we first need to examine students' abilities to learn and use scientific language and how their communicative abilities affect their content learning of science. In line with this principle, we analysed the pre-course demographic profile and English language competency of the students. Being a multi-racial country where different languages are commonly adopted (Chinese, English, Malay and Tamil), it was not unexpected that 50% freshmen spoke a different home language other than English. Between the two semesters, students who subscribed to the course in Semester 1 demonstrated better GP grades and speak more English at home. The distributions of these two variables suggest that students with stronger English ability are more likely to enrol in Semester 1. This might be attributed to two factors. Firstly, students who are confident in their English ability may self-select to read the course at an earlier stage of their candidature. Secondly, students who received a grade of D or below in the GCE A-Level GP are required to sit for a Qualifying English Test (QET). Students who do not perform optimally in the QET are required to read additional basic academic English courses before becoming eligible to enrol in the new course. Hence, students with poorer English competency and lower GP grade may not be able to enrol themselves in Semester 1. From an experimental perspective, this observation prompted our correction for variability in GP grade and home language to ensure accurate interpretation of findings related to other covariates. From a global perspective, this phenomenon is possibly mirrored in international universities where the underlying diversity of English language competency among freshmen may potentially be neglected during the teaching and learning of communication skills.

After establishing the student demography, we proceeded to interrogate the perceptions of the students on the effectiveness of the course. The mapping of self-reported responses between the pre- and post-course surveys

confirms that the course is effective in improving the students' competency and confidence in science communication (Figure 1). Additionally, a strong correlation (greater than 70%) between students' self-rated improvement and their perceived need for improvement was observed (Figure 2). Taken together, the students perceived the inaugural course to be effective in achieving its learning outcomes. Furthermore, teaching science communication earlier in the training process such as via a freshmen course potentially yields larger benefits as undergraduates imbibe the culture of communicating science with the general public as a necessary role of a scientist, parallel to the important responsibilities in researching science (Brownell, Price, & Steinman, 2013).

Text analysis of the reflection letters provided data on the positive and negative sentiments expressed by the students towards the course and its learning activities. In general, the number of positive opinions far surpassed the number of negative opinions and corroborated the positive learning outcomes. Nevertheless, negative opinions allowed the instructors to recognize current gaps associated with the course. For instance, the feedback on heavy workload may trigger recalibration of assignments to improve learning. The fact that students with better grades expressed both positive and negative opinions reflected the maturity of freshmen in learning and providing feedback. Presentation left a strong impression among the students as it attracted the most opinions. Our finding reinforces the importance of incorporating presentation as a classroom activity particularly for small class teaching.

To investigate the degree of students' engagement with the content of popular science books, we surveyed their underlying reading preferences and trends. Parkinson and Adendorff (2004) recommend the use of popular science articles for teaching scientific literacy, although they identified clear differences between the popular science genre and the research article and textbook genres which are more similar to each other. One major difference between popular science and the research article and textbook genres is the way in which knowledge is presented as provisional rather than as facts accepted by the scientific community. As explained by Parkinson and Adendorff (2004), the popular science genre facilitates the reading, thinking and critical response to knowledge presented in the current module. As students from the respective sub-disciplines may be more comfortable leveraging the discursive nature of the texts associated with their majors to generate the necessary discussion and analysis of targeted notions, this possibly explains their preferences of popular science books related directly or indirectly to their disciplines. Our postulation is further supported by Afonso and Gilbert (2013) who pointed out that popular science texts (chemistry) enable the informal engagement of chemistry knowledge where the focus on abstract concepts that are detached from technological applications and implications is minimized. The ease of

engagement with these familiar materials might present the students with rich examples of the essentials of science communication–of how science can be presented to facilitate the informal acquisition of scientific knowledge and thus, science education.

Based on the positive results obtained from the surveys, we finally proceeded to investigate the effects of several covariates on the perceived differential impact of the course. Using course grade as an impact measurement, we observed that female students were statistically less likely to receive a higher grade as compared to male students. This is a novel finding as it contradicted the local perception that female students are stronger in language. One plausible reason is that male students in our local context are typically two years older than female students because they have to serve the military national service prior to university education. The two additional pre-university years of military exposure appear to augment the competency of male students in writing and communication but this postulation needs to be tested. Additionally, scientific competence related to gender should be taken into account which was not investigated in the current study. Therefore, further investigation is needed to validate the effects of military conscription and gender-based scientific competence on the acquisition of communication competence.

In terms of declared majors, we observed impacts that are consistent with our anecdotal perceptions. For instance, Chemistry, Food, Science and Technology, and Life Sciences majors were found to be more likely to score better grades for the course than their Mathematics, Physics, and Statistics counterparts. This is possibly related to the differential demand in science writing and communication where students who major in Mathematics and Statistics tend to articulate their concepts via mathematical equations and formulae rather than essay writing. Peacock and Ho (2003) highlight sharp differences in language learning strategies or what they describe as differences in deficiencies of strategy use amongst students of different disciplines and raise the need for discipline-specific strategy. Hence, our finding holds important but often neglected pedagogical implications as students from different science majors may have different needs in learning of communication competency.

Based on our covariate analysis, we confirmed the better performance in the course is related to the pre-course English language competency of our freshmen as reflected by their correspondingly better GCE A-Level GP grade and spoken English language at home.

Contrary to course grade, students' self-reported improvement in writing and oral communication skills was not associated with any covariates, including students' self-assessment at the beginning of the course. In other words, students' perceived impact of the course was relatively less distinguishing among different sub-populations as compared to course grade.

On the other hand, students' greater confidence in post-course survey was found to be strongly associated with their correspondingly greater confidence at the beginning of the semester, English language spoken at home and better GCE A-Level GP grade. In other words, students who are confident remain confident while those who are less confident did not show significant improvement in terms of confidence in writing. Brownell, Price, and Steinman (2013) found that their students' perceived confidence level was enhanced by their undergraduate embedded science communication course in that their students expressed even higher levels of confidence on communicating science to laypersons and that they expressed more confidence in their written skills. They attributed the increased level of confidence to an extremely positive attitude about communicating science to the public right from the start of the course which translated into the harnessing of available opportunities to further develop and use these skills throughout the course. Hence, educators should take a longer term view in developing the confidence of students in science communication rather than relying on a single course.

CONCLUSION

In conclusion, our systematic research illuminated the underlying factors associated with the perceived impacts of an inaugural communication course offered to science freshmen. Specifically, this study contributes towards augmenting our appreciation of the epistemologies in the teaching and learning of communication within a multi-racial context and informs English language educators on the potential benefits of personalising the instructional design of a communication course for science freshmen. Future study on measuring the actual attainment of learning outcomes (e.g. development of coherence in writing and oral communication) by independent evaluators is essential to further inform and improve the instructional design of the course and learning experience of our students.

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REFERENCES

Afonso, A. S. & Gilbert, J. K. (2013). The role of 'popular books' in informal chemical education. *International Journal of Science Education*, *Part B*, *3*(1), 77–99. http://dx.doi.org/10.1080/21548455.2012.733439

Bok, D. (2006). *Our underachieving colleges: A candid look at how much students learn and why they should be learning more*. Princeton, NJ: Princeton University Press.

Brownell, S. E., Price, J. V. & Steinman, L. (2013). Science communication to the general public: Why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. *The Journal of Undergraduate Neuroscience Education*, *12*(1), E6 –E10. Retrieved from http://www.funjournal.org/wp-content/uploads/2015/09/june-12-e6.pdf.

Bullock, S. (2006). Building concepts through writing-to-learn in college physics classrooms. *Ontario Action Researcher, 9(2)*: 1–8. Retrieved from http://oar.nipissingu.ca/archive-V922E.htm.

Hathaway, J. (2015). Developing that voice: Locating academic writing tuition in the mainstream of higher education. *Teaching in Higher Education*, *20*(5), 506-517. http://dx.doi:org/10.1080/13562517.2015.1026891

Lea, M.R. (2004). Academic literacies: A pedagogy for course design. *Studies in Higher Education*, *29*(6), 739-756. http://dx.doi.org/10.1080/0307507042000287230

Mercer-Mapstone, L.D. & Kuchel, L. (2015). Core skills for effective science communication: a teaching resource for undergraduate science education. *International Journal of Science Education, Part B*, http://dx.doi.org/10.1080/21548455.2015.1113573

Mercer-Mapstone, L.D. & Matthews, K.E. (2017). Student perceptions of communication skills in undergraduate science at an Australian research-intensive university. *Assessment and Evaluation in Higher Education*, *42*(1), 98-114. http://dx.doi.org/10.1080/02602938.2015.1084492

Metcalfe, J. & Gascoigne, T. (2004, June). *The science communication professional in Australia*. Paper presented at the 2004 Public Communication of Science and Technology (PCST) International Conference, Barcelona, Spain.

Murray, N. & Nallaya, S. (2016). Embedding academic literacies in university programme curricula: A case study. *Studies in Higher Education*, *41*(7), 1296-1312. http://dx.doi.org/10.1080/03075079.2014.981150

Norris, S. P., Phillips, L. M. & Korpan, C. A. (2003). University students' interpretation of media reports of science and its relationship to background knowledge, interest, and reading difficulty. *Public Understanding of Science, 12*, 123-145. http://dx.doi.org/10.1177/09636625030122001

Parkinson, J. & Adendorff, R. (2004). The use of popular science articles in teaching scientific literacy. *English for Specific Purposes*, *23*(4), 379-396. http://dx.doi.org/10.1016/j.esp.2003.11.005

Peacock, M. & Ho, B. (2003). Students' language learning strategies across eight disciplines. *International Journal of Applied Linguistics*, *3*(2), 179–200. http://dx.doi.org/10.1111/1473-4192.00043

Quality Assurance Agency for Higher Education (2008). *Subject benchmark statements for subjects studied at honours degree level*. http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/subject-benchmark-statements/honours-degree-subjects.

Soules, A., Nielsen, S., LeDuc, D., Inouye, C., Singley, J., Wildy, E. & Seitz, J. (2014). Embedding multiple literacies into STEM curricula. *College Teaching, 62(4)*, 121-128. http://dx.doi.org/10.1080/87567555.2014.935699

Sweet, A.P. (2000). *Ten proven principles for teaching reading*. Washington, DC: U.S. Deptartment of Education, Office of Educational Research and Improvement, Educational Resources Information Center. Retrieved from http://www.nea.org/assets/docs/HE/mf_10proven.pdf.

Tang, K.S. (2015). A literature review of science communication. Retrieved from http://singteach.nie.edu.sg/issue50-research03/

Thompson, C.A., Eodice, M. & Tran, P. (2015). Student perceptions of general education requirements at a large public university: No surprises? *The Journal of General Education*, *64*(4), 278–293. http://dx.doi.org/10.5325/jgeneeduc.64.4.0278

Yin, R.K. (2009). *Case Study Research Design and Methods, Fourth Edition*. London, United Kingdom: SAGE Publications Ltd. ■

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