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A STUDENT-CENTRIC APPROACH FOR DEVELOPING SCIENTIFIC COMMUNICATION SKILLS IN UNDERGRADUATE MICROBIOLOGY STUDENTS

Aparna Talekar, Vivien Amonkar and Karuna Gokarn*
St. Xavier's College (Autonomous), Mumbai
karuna.gokarn@xaviers.edu

Scientific Communication is an important skill which needs to be developed in students for building a successful career in science. Here, we report the design and development of a student-centric, activity-based course in scientific communication skills (SCS) for undergraduate Microbiology students. We followed a pedagogical strategy that allowed for integration of assessment with the learning activities. The effectiveness of the course was measured by administering questionnaires to the students both before and after the course. The comparison between the results of the pre- and post-intervention questionnaires revealed that the students demonstrated an overall increase in their understanding of key concepts essential for SCS after undertaking the course. This report, even though preliminary, highlights the importance of developing a student-centric course in SCS at the undergraduate level.

INTRODUCTION

Proficiency in scientific communication is an important goal of undergraduate science education. As tertiary level science degree programs form the foundation of the life sciences sector by providing skilled manpower, it has been proposed that formal communication in science courses be introduced at this early stage of career development (Anderson & Helms, 2001; Spektor-Levy, Eylon, & Scherz, 2009). The major aim of such courses is to enable students to develop an ability to locate and retrieve relevant information, to critically evaluate information; to analyse and organize the information; to draw inferences based on evidence; and to be able to disseminate the acquired knowledge in an appropriate form by different modes of communication (NRC, 2012; McComas, 2014). Besides, a course in Scientific Communication Skills (SCS) may also assist students to verbalize their understanding of a subject matter for themselves and self-evaluate their own learning (Murray & Hughes, 2008). However, it has been observed that STEM students often find communicating 'science' a challenging task and traditional courses fail to build the necessary skills required (Grant, Liu, & Gardella, 2015). Therefore, it is essential to develop a course which integrates learning activities incorporated with tasks that aid in understanding the concepts and terms of the subject matter, and at the same time, engage the student in acquiring skills required for communicating their learning (Hurd, 2000). In this regard, an SCS course was introduced to second-year undergraduate science students of St. Xavier's College (Autonomous), Mumbai University in June 2011. Initially, a semester-long, one credit (15 contact hour) course was developed as a series of hands-on activities purposefully designed for better conceptual understanding of the subject matter. The core syllabus of the SCS module offered in the third

semester almost remained the same, however, the pedagogy was modified to be more student centric and activity based. The instructors noticed that just the theory of SCS was not enough for the students to understand and apply the concepts of SCS. Thus, the SCS course module was modified and extended to Semester 4 where the students were asked to apply the skills in writing their laboratory projects (proposal, poster, project report, manuscript and presentation) which is evaluated as a part of SCS course.

Here, we elaborate upon the course design and its impact on students evaluated by a questionnaire administered to the students both before and after the first half of the course. We also note the qualitative differences observed in the students' responses and how it has served as a feedback for evolving and improving the course over the last seven years.

METHODS

Course Design and Execution

The SCS course in Microbiology has been divided into six modules spanning over two semesters. While the focus of the earlier semester (third) is the comprehension of various aspects of scientific communication, the latter semester (fourth) deals with the application of the concepts learned.

The first module of the course requires that the students create mind maps on any Microbiology topic chosen by them (in consultation with the mentors) and convert it into a chart or a model to be presented in the annual exhibition organized for the orientation of the first-year Bachelor of Science students. One example of a mind map and the corresponding chart prepared by the student is shown in Figure 1 (Matthews & Matthews, 2008; Buzan & Buzan, 1993).

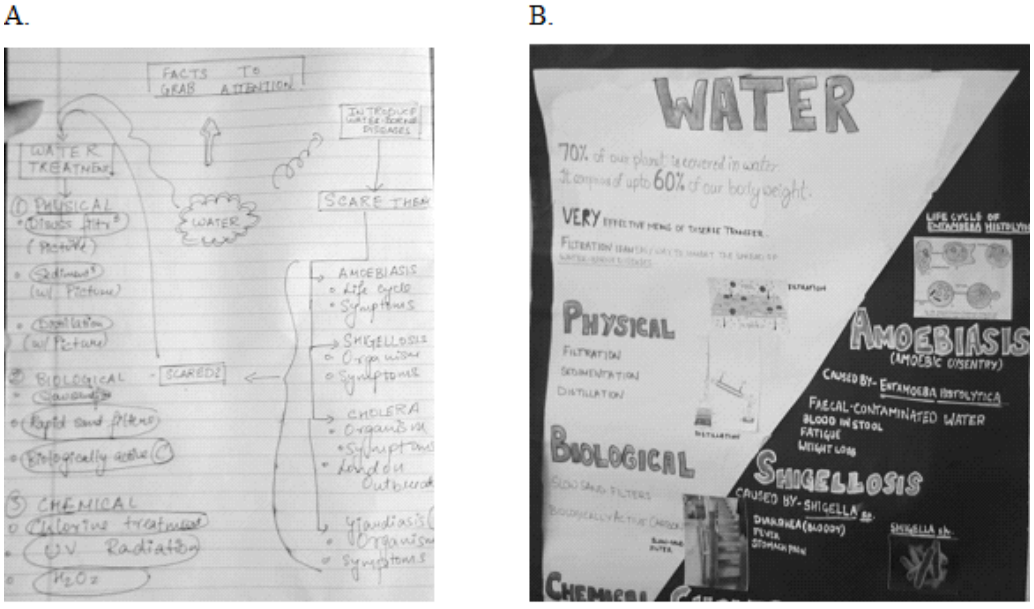

Figure 1: A) An example of a mind map prepared by a student B) shows the corresponding chart made by the same student.

This activity engages the students in researching the literature, retrieving the relevant information, organizing the information and finally verbalizing their assimilated knowledge. The effectiveness of mind maps in organizing information and developing knowledge structures has been established earlier (Buzan & Buzan, 1993) . The evaluation of this task is done by mentors who visit each exhibit (chart/model) and assess it for the relevance of content, comprehensiveness, and clarity. The students are also assessed for their verbal explanation of the chosen topic to the visitors/mentors. We have observed that not only does this task act as an ice breaker between the freshers and the sophomore students but it also develops a sense of self-efficacy among the second-year students.

The next module deals with comprehending technical information and summarizing it. The students are first sensitized to crucial elements of summary writing and then given short research articles or popular science commentaries (audio-visual) relevant to the discipline to summarize in their own words (word limit: 150). It has been reported that summarizing in their own words helps students in comprehension of new information which is an indicator of student learning (Haystead and Marzano, 2009). The difference between a summary and an abstract is also emphasized. The evaluation involves summarizing scientific information provided to students in the form of an audio-visual documentary or a science topic-based film. The use of varied modes of scientific information challenges the students with multisensory inputs and fosters comprehension skills that promote learning (Blomert & Froyen, 2010; Clark, Nguyen, & Sweller, 2006).

The next three modules were designed based on our observation that undergraduate students often struggle with understanding research articles and find it challenging to grasp technical information. Similar difficulties faced by students globally have also been reported (Goldbort, 2006). Proficiency in scientific communication necessarily requires understanding the elements of a good scientific report/research articles. Hence, students are initially introduced to components of a scientific write-up, generally a research article (Murray & Hughes, 2008). One of the most important aspects discussed in detail is ‘plagiarism’. Students’ difficulty with recognizing and understanding the concept of plagiarism is a challenge faced by educators worldwide (Dawson & Overfield, 2006). The concept was dealt with as a series of discussions with exemplars of plagiarism, paraphrasing, and citations extracted from several kinds of scientific literature. Students are also made aware of software available for detection of plagiarism (eg: Turnitin and a free tool available online-SEO plagiarism checker). The idea is to sensitize students to the importance of maintaining academic integrity and avoiding plagiarism. Further, the students are introduced to various sections of a primary research article and familiarized with the IMRaD format (Sollaci & Pereira, 2004). Students are then engaged in a group reading exercise where they try to understand a simple research paper by paying attention to its title, abstract and other sections up to the references as per the standard guidelines (Hoogenboom & Manske, 2012). Generally, the instructors ensure to give research articles from different peer-reviewed journals to familiarize the students to the fact that different journals may follow slightly different formats. This is followed by a discussion of the papers read (2-3 papers) in the class by the groups to share their perspectives with their peers. The papers assigned to the class are usually chosen from the field of Microbiology and mostly have methodologies familiar to students. The final learning task of the course in this semester is critiquing a research paper which is carried out as a group discussion activity moderated by the instructor. The students are divided into groups of 10-12 students and allowed to read and discuss 2-3 papers. This interpersonal exchange of ideas encourages

peer learning, teamwork and developing soft skills of a student (Besley & Tanner, 2011). Students are also introduced to allied concepts such as peer review, open access articles and bibliometric databases such as Web of Science and Scopus. The final evaluation for this course involves writing a critical review of a research paper from a journal for them to understand the importance of publishing in peer-reviewed journals. All the aspects learned throughout the semester are assessed in this activity such as students' attention to the relevance of the title, comprehensiveness of the abstract, appropriate literature citations, checking for plagiarism and referencing style. The advanced part of this course is dealt with as an integrated activity with the disciplinary research projects undertaken by students in the next semester (fourth). The students are introduced to literature reviews, referencing styles, reading different types of research reports and other activities. The students write their own project proposals before embarking upon the research projects which are ratified by the mentors. The learnings from both the semesters culminate in the form of a scientific report, a poster and an oral presentation for summarizing their work which forms a part of an assessment for the SCS course.

Participants

The SCS course typically accommodates 33-37 student participants for this study, per year. The students belong to the second year of Bachelor of Science course in Microbiology with an average age of 19 years. The course spans 2 semesters of the year. The number of credits is one per semester and the number of contact hours is 15 per semester.

Questionnaire Design

The course in SCS started in 2011. Although the need for an SCS course was apparent, we began to ponder over the effectiveness of the course after a few years of its inception. We took oral/written feedback from the students to assess the efficacy of the course. In order to formalize the assessment, a questionnaire was designed to evaluate the impact of the course on the students during the last year. The questionnaire was designed based on the modules and what the students are expected to know after the course was completed. Since most students joining the course come with little prior knowledge or familiarity with the topic, the questionnaire comprised of questions about general aspects of scientific communication and was administered to students before the beginning of the course (before the third semester designated as pre-intervention questionnaire) to gauge a baseline understanding of the students for the topic. The students are given 30 min for answering the questions. The questionnaire was also administered at the end of Semester 3 (after the end of the first half of the course designated as post-intervention questionnaire). Over the years, the questionnaire has evolved based on the responses of the students. A sample of the common questionnaire used in the study is given in Table 1.

The questions were purposefully designed to be open-ended in nature to serve as a formative assessment and provide an insight into alternative conceptions of the students. As detailed earlier, in the third semester, the students are exposed to activities for comprehending various aspects of scientific communication while in the fourth semester, they apply all their learning to write a research report. Therefore, a similar questionnaire is administered again to the students at the end of the fourth semester to assess whether the reiteration of concepts leads to the enhanced grasping of the topics. However, in this report, we only present examples from student responses from the questionnaire administered before and after the third semester.

Sr. No.	Question	Responses – Pre- intervention questionnaire	Responses – Post- intervention questionnaire
Q.1	Give an example of plagiarism. You may create one.	• Copy-pasting matter from the internet • Using research material without permission from the publisher • Don't know • Stealing someone's idea • Violating copyright	• When a researcher copy-pastes some writing from another paper • When something is written as it is without paraphrasing • A research paper published in one country has the same publication in another country in a different journal • Copying the same words
Q.2	What do you understand by paraphrasing? Explain with the example you have given as an answer to Q.1.	• To explain in one's own work • Summarising someone's work • Don't know • To reduce the size of a big paragraph • Gives credit to the inventor	• Modification of a sentence so that the meaning remains the same • Write a sentence in one's own words after understanding the essence of the given content • Understand the meaning and then write in one's own words • Rewriting in one's own words without the meaning being lost
Q.3	How would you differentiate between a review article and a research paper?	• A research paper talks about one's discoveries, whereas, review article you critique someone's paper • A research paper is writing about the experiment, whereas, a review article is one's opinion of a research article • Don't know • A research paper is scientifically proven, whereas, a review article is theoretical	• A review article is to critique a paper; research paper gives details • A review is like a summary of many research papers put together; research paper follows the IMRaD format • A review article is not in much detail; research paper gives all details • Review article does not follow IMRaD format; research paper does
Q.4	How is a summary different from an abstract?	• A summary is a scientific content; abstract is something which is thought by a person • A summary is a detailed explanation; abstract is a short mind map • A summary is a whole story or idea explained in short; abstract is all important points about the idea • A summary is something written in brief; abstract is a visual summary	• A summary is an overview of an experiment, abstract gives an idea of the paper • A summary can be written for an article, an abstract is written only for research papers • A summary is a discussion of the article in short. Abstract highlights the main points of the research paper • A summary is a shorthand version of a full-length article or paper; abstract is like a brief preview of the research paper
Q.5	If you were to write a reference for your research paper, how would you write it? Show this as an example of a reference.	• Don't know • Paper on ABC by Mr. X pgs- 1-2 • Not relevant • Write the page and article number and name of the paper	• Authors, XYZ, journal name • XYZ, authors, journal name • Authors, journal name, XYZ • Author surname, initials, year

Sr. No.	Question	Responses – Pre- intervention questionnaire	Responses – Post- intervention questionnaire
Q.6	Write down the subtitles you would use to write a proposal.	• Don't know • I did not understand • Not applicable • Theory abstract result conclusion	• Introduction, materials, and methods; applications, expected results • Introduction, materials, and methods; applications, expected results, the relevance of the project, budget • Introduction, materials, and methods; applications, expected results, budget, references

Table 1: Questionnaire with examples of pre-intervention and post-intervention Responses

Data Analysis

The responses obtained from the administration of the questionnaire was assessed qualitatively as well as quantitatively. The correct responses were designated as positive responses and the comparative data between the pre- and post-intervention questionnaire is presented as a bar chart (Figure 2). Further, a qualitative analysis was done of the student responses received both before and after the course which served as indicators of a change in student responses. Some randomly chosen responses from both the pre- and post-intervention questionnaire have been presented in Table 1.

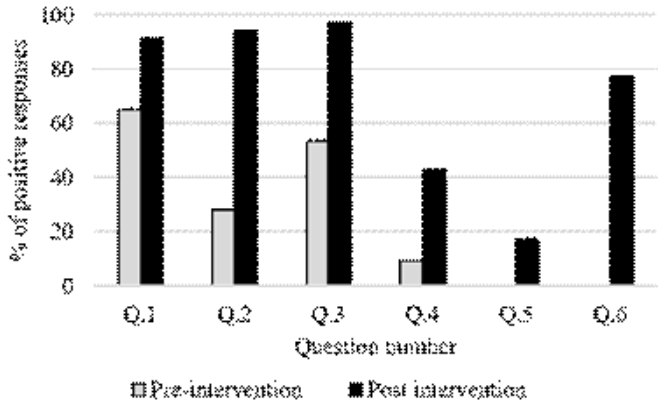

Figure 2: The percentage of positive responses obtained from the students for the administered questionnaire before (pre-intervention) and after (post-intervention) the course is represented on the Y-axis while the number of the question is represented on the X-axis.

RESULTS AND DISCUSSION

The percentage of positive responses obtained by administration of the pre- and the post-intervention questionnaires to students is presented in Figure 2. An overall increase in the number of positive responses was observed across all the six questions. The maximum increase (77.14%) was observed for question number 6 while the lowest change (17.14%) was recorded for question number 5. It was noted that even though students were aware of the concept of plagiarism (Q.1), they did not know about paraphrasing (Q.2).

Most students associated paraphrasing with either shortening the length of the content, summarising the content or writing the same content but giving credit to the original author (Table 1). However, after the course, most students correctly stated the meaning of paraphrasing as writing the content in one's own words after understanding the essence of the original text. This aspect was dealt in the class with several examples of paraphrasing and extended discussions. Based on the formative assessments and feedbacks over the years, it was realized that merely apprising students about plagiarism did not help them in correcting their mistakes while active group discussions in class with varied examples remedied the problem. This was also evident in the examples created by the students as a response to Q.1. Almost none of the students could create an example for Q.1 in the pre-intervention questionnaire. Many did so in the post-intervention questionnaire. An example given by one of the students was "Plaque assay is much similar to viable count" stated as is as plagiarism and modified as "There are various similarities in viable count and plaque assay" for paraphrasing in Q.2. Another example given for Q.1 was "The cellulose degraders were isolated from soil samples and were enriched in MacBeth's medium" and modified as "Soil sample was used to isolate cellulase enzyme producers. MacBeth's broth was used to enrich them." for Q.2.Further, it was observed that students had minimal or no understanding of research articles in general. Most students did not understand the difference between a research and a review article (Q.3) or between an abstract and a summary (Q.4). Most students associated an abstract with a research article only after the course. Students also had minimal or no understanding of the concepts of reference writing before the course which increased marginally after the course (Q.5) (Table 1). However, it was noted that reference writing skills improved substantially after the fourth-semester course where the topic was dealt in much detail and they actually applied it to write the references in their project reports (data not shared in this report). Overall, a change in the vocabulary of the answers was observed where students' usage of technical terms increased in the responses after the course. The activity on critiquing of the primary journal article used for evaluation of module 6 of the course gave an insight into the learning of the students. A few students understood the abstract as something of a prelude to a journal article which does not necessarily outline results. Also, many students critiqued the absence of a detailed method for standard protocols which are generally cited as previous publications in most research articles. Additionally, most students only wrote about the negative aspects of the given article; although we did expect the students to appreciate the well-written portions of the articles too. Most of these issues are discussed with students in the next semester, though we also plan to address these with the next batch of incoming students in the third semester. Since, the students were not exposed to any course on scientific communication skills in their previous years of study, the changes observed in the students' understanding of the subject matter may be attributed to the SCS course module attended in the college.

LIMITATIONS OF THE STUDY

We recognized a lack of general communication skills in English in a few students which made it difficult for us to evaluate their understanding properly. Even though we realize that proficiency in English is a primary requirement for developing effective SCS, currently our course does not address the problem.

We started the course on SCS in the year 2011 with some modules which were activity-based. Every year we observed students, took their feedback and went on revising the course. It has been our observation that

student learning improved as we went on designing activity-based classes. Even though we took feedback of the course every year both during the course and at the end of the course, we did not systematically record the student learning data over the early few years. The data that we present in this study is derived from the last year only. There is no quasi control for this study where a similar course without following activity-based methods was delivered and could be used for comparison. However, an elaborate study with an appropriate control group of students and using standard tools for measuring student learning as a proof of concept is now underway for the current year. The data presented in this report is preliminary and is part of the current ongoing study.

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