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Foundation Skills for Scientists: An Evolving Program

Teresa Dawson
University of Victoria, tdawson@uvic.ca

Sarah Fedko
University of Toronto Scarborough, sfedko@utsc.utoronto.ca

Nancy Johnston
University of Toronto Scarborough, johnston@utsc.utoronto.ca

Elaine Khoo
University of Toronto Scarborough, khoo@utsc.utoronto.ca

Sarah King
University of Toronto Scarborough, sking@utsc.utoronto.ca

See next page for additional authors

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Foundation Skills for Scientists: An Evolving Program

Abstract
We have undertaken an integrated and collaborative approach to developing foundational skills of students in a first year, Introductory Biology course. The course is a large lecture and laboratory course with enrollments ranging from 800-1000 per year. Teaching and Learning experts were brought into the course as weekly 'Foundation Skills for Scientists' sessions were created. The initial challenges were to have effective knowledge exchange between collaborators and create an integrated course syllabus. Once effective sessions were created, the next challenge was to improve student valuation of them. High value was only achieved when the skill sessions were tightly linked to course assignments and activities and was delivered 'just in time'. Even then, the challenge has been to motivate students to realize that the sessions are directly relevant to them. Overall, student performance has improved since the program was initiated as measured by rate of retention in the course, overall course marks and quality of writing. Nous avons utilisé une approche intégrée et collaborative pour approfondir les compétences de base des étudiants de première année qui suivent un cours d'introduction à la biologie. Il s'agit d'un cours magistral et en laboratoire, auquel s'inscrivent entre 800 et 1000 étudiants par an. Ce cours a bénéficié de l'apport d'experts en enseignement et en apprentissage afin d'appuyer le développement de séances hebdomadaires portant sur les compétences de base en sciences. Les difficultés initiales étaient de susciter un échange de connaissances efficace entre les collaborateurs et de créer un plan de cours intégré. Une fois les séances organisées, la difficulté suivante a été de faire en sorte que les étudiants les apprécient davantage. Ces derniers les ont jugées très utiles uniquement lorsqu'elles étaient étroitement liées aux tâches et aux activités et lorsqu'elles étaient offertes au moment opportun. Même alors, le défi a consisté à motiver les étudiants afin qu'ils se rendent compte que les séances leur sont directement pertinentes. Dans l'ensemble, la performance des étudiants s'est améliorée depuis le début du programme comme l'indiquent les mesures du taux de persévérance dans le cours, les notes générales et la qualité de la rédaction.

Keywords
self-efficacy, curriculum alignment, scaffolding, skill development, collaborative approaches

Cover Page Footnote
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Authors
Teresa Dawson, Sarah Fedko, Nancy Johnston, Elaine Khoo, Sarah King, Saira Mall, Mary Olaveson, Janice Patterson, Kamini Persaud, Frances Sardone, Zohreh Shahbazi, Allyson Skene, Martha Young, and Clare A. Hasenkampf

Science literacy is an increasingly important goal for our increasingly technological society. Science literacy includes an understanding of fundamental aspects of the natural world, the relationship between science, math, technology, and the human condition, as well as an understanding of the nature of scientific inquiry (McDonald & Dominquez, 2005). In 1996, the National Research Council of the United States set four national standards for Science Education (NRC, 1996): (a) Experience the richness and excitement of knowing about and understanding the natural world; (b) Use appropriate scientific processes and principles in making personal decisions; (c) Engage intelligently in public discourse and debate about matters of scientific and technological concern; and (d) Increase economic productivity through the use of knowledge and skills of the scientifically literate. In short, science literacy is about having students see the scientific endeavour, not as some esoteric other worldly realm but rather as an approach to understanding the natural world in which we live. With this attitude, the skills acquired with a science education become the skills to achieve personal and societal goals.

Beyond "just science," our global society has become so complex (Barnett, 2000) that universities must be places not just for developing the ideas and technologies to cope with our rapidly changing world but also where the next generation of research-savvy citizens and leaders are trained. The Boyer Commission (1998) report on Educating Undergraduates in the Research Universities underscores the importance of teaching university students to acquire critical thinking skills, especially those of analysis, evaluation, and synthesis. The Boyer Commission specifically looks to research-intensive universities to provide training in research techniques and to provide research opportunities for all of its willing students.

Research universities are rich in research expertise and are major sites of knowledge generation. Most researchers are familiar with the age-old apprenticeship approach to the training of the next generation researcher. Unfortunately, there is no absolute link between the ability to do research and the far less familiar ability to train large numbers of students in research skills. Therefore, 10 years after the Boyer Commission's report, research-intensive universities are still grappling with how to train undergraduates to use the skill sets of researchers for course work in their discipline and, more important, for their crucial roles as leaders and leading citizens capable of grappling with the complex and changing world landscape.

Fortunately university faculty are entering into the fray and finding ways to help students adopt a research-based (inquiry-based) approach to assessing information and developing new knowledge and applications. Healey and Jenkins (2006) consider how to strengthen the linkage between teaching and research through the university curriculum (their exhibit 5.1, p. 49). They recommend that undergraduate programs develop students' understanding of the role of research in their disciplines(s) and that there be a progressive development of students' understanding. First year courses are called on to be inquiry based, requiring students to construct, interpret, and disseminate knowledge (Healey & Jenkins, 2006). Their recommendations echo those of the Boyer Commission, and the bonus is that students who engage with the material at this deep level will remember the essential material longer (Anderson & Krathwohl, 2001) and will achieve more sophisticated views of the world (Healey & Jenkins, 2006).

At our campus, faculty in the Biological Sciences have entered into an ongoing collaboration with faculty in the Centre for Teaching and Learning (CTL) to help bring academic skills into the foreground in the large Introductory Biology class. The collaboration is called <u>F</u>oundation <u>S</u>kills for <u>S</u>cientists (known as FS squared-FS^2), and the goal is to have students enhance their academic skills and transition to a research-based approach to knowledge, in effect to transition from being students in a science course to becoming scientists in training. BGYA01 is the only introductory biology course at the campus, so it is effectively a multipurpose course. It is the gateway course to all other courses in biology, but only about half of the students are interested in pursuing a biology degree. The remaining students are pursuing degrees in related disciplines (e.g., Psychology or Health Studies) or are taking the course solely for interest. The course does not have any secondary school or university prerequisites, but the vast majority of students have had biology in grade 12. Students entering this course typically have a variety of motivations and skill levels. Our aspirations for all of them are the same: to enable them to become critical thinkers about the science of biology and to develop their research and communication skills. As well, we hope they will expand and enrich their understanding of the field of biology.

We wanted to help motivate students to do deep learning and improve their self-efficacy as scientists. Evidence suggests that self-efficacy (in our case for students to become confident that they can function as scientists) is achieved as students develop progressive mastery over a carefully sequenced set of smaller goals (Crooks, 1988). Thus in the collaboration of biologists with writing specialists, information literacy and research skills librarians, qualitative and quantitative reasoning experts, and study skills advisors, we have worked to bridge the distance between the research skills of the course instructors and those of the students by helping students break complex assignments down into a series of manageable tasks. By bringing a student-focused learning perspective, the learning specialists have helped scaffold course goals and assignments and, in doing so, have helped students improve their foundational skills and performance in the course.

While the primary goal of our collaboration has been to help align the learning goals of Introductory Biology more thoroughly with students' activities and assignments, another important goal has been to develop a model for faculty collaboration involving continuous planning and improvement (Briggs, 2007). Through official meetings and casual dialogues, we have been learning to integrate the expertise of both scientists and learning specialists to design and redesign FS^2 sessions in an iterative fashion that has progressively helped students develop their own expertise. This FS^2 experience is helping teaching and learning specialists to work more effectively with discipline faculty, is establishing vital linkages with departments that can help them align their program goals with their teaching practices, and may help promulgate a campus-wide reflective model for curriculum development and assessment (Biggs, 2001).

Methods

Project History and Process

We first added FS^2 skill sessions to Introductory Biology in the fall of 2004. Students in the course attend two lecture hours per week plus one 3-hour lab. In order to add skills development to the course without sacrificing biology content, the decision was made to add a third weekly lecture hour. This allowed for ten 50-minute FS^2 skill development sessions to help students achieve the course learning goals. In order to develop the curriculum, biologists communicated learning goals, described assignments, and explained past challenges to CTL learning experts in writing, mathematics, presentation skills, and information literacy. Biologists and CTL specialists then worked together to develop topics and content for the sessions. By carefully integrating skill development with discipline-specific course content, we strove to avoid any notion that skill acquisition is separate and distinct from disciplinary discourse. Hence we created skill sessions that were integrated into a science course and “scaffolded” the assignments and activities of the course.

Constructive alignment (Biggs & Tang, 2007) has been an underlying principle throughout the ongoing and cyclical process of planning, teaching, and assessing FS^2. We have worked hard to align the different elements of the BGYA01 course with the FS^2 intervention in three ways:

1. just-in-time FS^2 lectures that deal with areas of pressing need at the time students are most likely to need them—e.g. data analysis the week students are collecting data; report writing sessions the week before students will be handing in a lab report, and so on.
2. scaffolding that enables the alignment of student output (in this case the lab report) and instructor’s expectations about the length and quality of lab reports.
3. explicit expression of goals and expectations such that these can be understood and shared by the three most vested parties: biology instructors, students, and TAs.

Once the activities for the biology lectures, biology labs, and FS^2 skill sessions were determined, an integrated course syllabus had to be created. This was a major challenge of the collaboration. Creating an integrated syllabus that provided a logical flow to biology content, linked biology lectures to experiments done in the lab, and provided “just in time” scaffolding skill sessions that supported learning and assignment success is a logistical challenge that each year requires the good will and ingenuity of all collaborators.

At the end of the first term we conducted focus groups with students, and CTL specialists and Biology instructors debriefed each other. We then changed session content somewhat to meet student suggestions, but mostly changing the order of topics to more closely align with the skills required of students in the course. While the details changed every time the course was offered, three major areas evolved: the scientific method and communication, data analysis, and understanding and achieving university expectations.

FS^2 Sessions

Scientific communication. The student’s biology lab report, as a model of scientific investigation, has been a major focal point of the FS^2 endeavour. Several FS^2 sessions were devoted to developing and testing hypotheses, deconstructing a research paper, and constructing a lab report that models a research publication. In creating lectures and materials to support students in writing their lab reports, writing specialists focused on modeling best practices through both teaching and using samples and on linking the lab report to professional scientific papers. In three hour-long lectures assigned to writing the lab report, we adopted a variety of strategies to sensitize students to the conventions and purpose of scientific communication, of the structure of the lab report, and the conventions of scientific writing. We showed students a peer-reviewed empirical study by one of the course instructors and demonstrated how its structure follows precisely the same basic IMRaD (Introduction, Methods, Results and Discussion) structure as their assigned lab report. Following this holistic introduction, we broke down both process and product, teaching the lab report in three modules, in the order we suggested students write them—beginning with the Materials and Methods section and ending with the Introduction and Discussion sections. For each section, we offered clear instructions and showed examples. In the examples, we highlighted stylistic points important to scientific writing—for example, when to use the past tense or the passive voice—and drew students' attention to in-text citations and to the conventions for citation. We modeled, in our own lectures, the process of giving credit to sources by including a "References" slide. Finally, in order to ensure alignment between student and instructor expectations, we developed a closely correlated grading rubric for TAs and a Self-Evaluation Checklist for students.

In sum, we built the writing instruction around three principles: locating student writing assignment in larger context of scientific writing and communication as knowledge-building, scaffolding process and product, showing examples for everything and modeling best practices ourselves. Although we showed them (rather than told them) how to approach the preparation of each section of the lab report, students had to engage in a substantial amount of construction of knowledge—the "constructive" aspect of alignment. For instance, when we first introduced how to write a lab report based on an experiment, we defined an experimental situation that paralleled what students had carried out in the lab. Our session on how to write each section of the report was based on our hypothetical experiment. Students then needed to understand the parallel between our "lab report" section examples and their real-life lab report, so there was a need on their part to construct the learning for their own lab report writing experience. This constructive aspect of the alignment was necessary to ensure that students did not imitate an exemplary paragraph. Instead, the alignment served as scaffolding for bridging the gap between their knowledge/skills and where they need to be communicating. This scaffolding was important for another reason: A large proportion of the students were nonnative speakers of English, and many were international students from cultures where writing norms may be quite different from those of the North American research university. The writing instruction was one of the most successful modules in the pilot, and while the details have evolved over the years, it has remained relatively consistent.

Data analysis. Like the writing sessions, the data analysis sessions were also directed towards the lab report, in the sense of preparing the data. We began by discussing the basic concepts and principles of probability, using examples selected to help students understand more profoundly the underlying mathematical formulations of the lab they would be writing up. Students were required to estimate a certain population size through sampling using Mark Recaptured method. Then they were introduced to various methods to assess the reliability of their estimations using basic statistical tests. One reason students frequently do not learn math-related concepts is that they do not easily see how and why mathematical concepts and methods are applicable to their specific field and future career. The lab report, which requires students to perform basic statistical tests, embeds math into students' discipline-based demands and hence gives them a clear incentive to learn mathematics concepts that will be directly relevant to their future research activities.

Understanding and meeting university expectations. Goldfinch and Hughes (2007) did a study of students' self-perception of their skills in autonomy (time management, ability to set goals, and self-evaluation), note-taking, numeracy, problem solving, information technology, and written and oral communications. They report that, on average, students who rated themselves highest in all skills, except those skills relating to autonomy, were most likely to fail the course. Students who rated themselves lowest across the board were most likely to drop out. Interestingly, students who rated themselves highest in the autonomy category but more modestly in the other skills were the group most likely to stay and pass their first year courses.

We felt it was important to quickly help students assess their own skill levels. Initially, the FS^2 sessions in the first and second week of class considered transitioning to university, time management, and study skills. We reasoned that the sooner students improved in these areas, the more it would impact their success. However, anecdotal information from students indicated that these sessions were not received well. There were no contextualized examples of cognitive levels, and many students did not perceive themselves as needing improvement; they had not yet been asked to perform in the context of university tests.

In the Fall 2007 term, we set out to improve the effectiveness of these sessions. We knew that it was important that: (a) students understand what it means to operate at higher cognitive levels, (b) we give them early opportunities to try, and (c) students quickly attain skills at time management and studying effectively. To meet these goals, yet do it in a manner that would be valued by students, we reordered our topics somewhat. We decided to focus the first session on welcoming students into the scientific community, and a biology faculty member gave them a glimpse of the exciting research occurring on their campus. Then we highlighted how the scientists had to work at many cognitive levels to pursue their research projects. Since FS^2 sessions were on Fridays, by the time the second FS^2 session had occurred, there had been four class meetings on biology content. At the second FS^2 meeting, the session began with a "pop," multiple-choice "clicker" quiz related to the content of the four lectures. Students were asked to "click in" their response, and students were asked to jot down the question number and their answer (a, b, c, d, or e) on a piece of paper for each question. After students had completed the quiz, each question was posted again along with the histogram of student answers. The correct answer was given for each question, as were Bloom's cognitive levels (1956). Two questions tested simple recall, one tested understanding, one tested the ability to analyze, and one tested problem solving. This quiz debriefing provided students clear examples of the cognitive levels in the context of this course and enabled them to see where they were functioning. The quiz and debriefing session took about 20 minutes. The remaining 30 minutes was spent on time management and study skills as well as on how to find additional help on campus for both. Student reactions and subsequent surveys showed student approval of the new approach. Thus, by making some simple changes—making the goal more significant (relevant to a career as a scientist), making the objectives more clear with quiz examples, and by giving early feedback on their current abilities—student valuation of the sessions on cognitive levels, time management, and study skills greatly improved.

Strategy for Future Iterations

Plans for changes to the FS^2 curriculum are ongoing. In 2008, we moved the session on academic planning out of the Fall term, as it was not "just in time" (registration for the following year does not occur until spring) and instead had a session on information literacy and searching the literature. It was not as well received as we would like. The ratio of positive to negative responses was 2:1, and 28.6% of students were not sure if they agreed or disagreed. We will take a cue from our success with the session on cognitive levels and study skills and try to make it clearer how information literacy/research skills are essential for working scientists, and we will embed the need for research skills more extensively in their experiment planning and lab report.

Methods for Assessing Our Success

Our FS^2 project is an evolving one, as each year we reflect upon our perceived successes and failures. For these reflections we considered our own experience within the session, student retention and performance, and student opinion. We then revised the FS^2 sessions as appropriate. Student performance was measured in three ways, using two different cohorts. The first cohort consisted of students who took Introductory Biology in 2003, the year *before* FS^2 was introduced. The second cohort was composed of students who took Introductory Biology in 2005, *with* the second iteration of FS^2. For each cohort we looked at the percentage of the students who were in the course at the end of the "shopping period" who completed the course (completion rate). We also looked at the grades the students earned in the course overall. Last, the quality of the writing assignments was examined. For the writing analysis, students in both 2003 and 2005 were asked to provide their marked lab reports for our study. Students with higher marks were more likely to provide their reports. The number of samples available for 2003 was limited, and the only way to obtain comparable samples was to examine 14 reports from each year that received scores of 90 or above. Dates and names were removed from the papers, and the papers were given to one of the writing specialists to assess. Overall quality of writing was marked on a Likert-like scale of 1- 6 (1= *little effort demonstrated*, 2 = *poor grasp of science writing as well as poor grammar*, 3 = *some semblance to scientific writing [superficial appearance] but conspicuous writing errors*, 4 = *good attempt in conveying content and making reasonably good use of academic language*, 5 = *good attempt in expressing scientific journal style and generally easy to understand, with minor language errors*, and 6 = *a reasonably close resemblance to a biology journal format and style [considering first year level] and good grammatical usage throughout*).

Student opinion and perspective were obtained through anonymous surveys done in the last week of classes. These surveys were conducted in 2005 and 2007. Students were asked to indicate if each FS^2 session was helpful to them, using a 5-point Likert scale (1 = *strongly agree*, 2 = *agree*, 3 = *can't decide*, 4 = *disagree*, 5 = *strongly disagree*). For each session's survey question, the ratio of positive to negative responses was calculated and scrutinized to determine trends.

Results

Self-Efficacy

We reasoned that if FS^2 sessions were helping students feel more empowered to handle the demands of the course, then fewer students would drop the course. We tested this by comparing course completion rates in pre- and post- FS^2 cohorts. Course completion rates for the 2005 (post-FS^2) cohort improved over the 2003 one, from 94.6% to 97.3% (see Table 1). This 2.7% increase is statistically significant ($X^2(1) = 22.6$, $p < .001$) and represents an additional 22 students completing the course.

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Table 1
Comparison of BGYA01Course Completion Rates in Pre- and Post-FS^2 Cohort

Year	2003 (pre-FS²)	2005 (FS²/BGYA01)
Students enrolled	1,025	827
Students completed	970	805
Percentage students retained	94.6	97.3

Student Performance in Terms of Course Grades

Grades impact students' perceptions of their own learning and, although not a direct goal of the FS^2 innovation, one of the associated outcomes of FS^2 was a general improvement in students' course grades on the midterm and final exams. In 2003, the mean score on the final exam was 62.5%, with a standard deviation (*SD*) of 13.1; in 2005 the mean was 66.2% with a *SD* of 14.2. This 3.7% improvement in performance was statistically significant when examined using a *t* test (two-tailed, $t(1,606) = 5.39$, $p < .001$).

Not only did student grades increase overall, but a comparison of the grade distribution among students in the pre- and post-FS^2 cohorts indicated a marked increase in numbers in the A grade category and a relative reduction in the other categories (see Figure 1). The class *average* on the final exam increased from 62.5% to 66.12%. However, the *distribution* of final grades showed a 12.7% increase in A grades and an average decrease in all other grades of 3.17%, with the most dramatic decreases in the C grades (by 4.3%) and F grades (by 4%). We found that in 2005, 70.4% of the class was achieving grades of C and better, an increase of 6.8% from 2003 (in an institution which, it should be pointed out, prides itself on taking steps to minimize grade inflation).

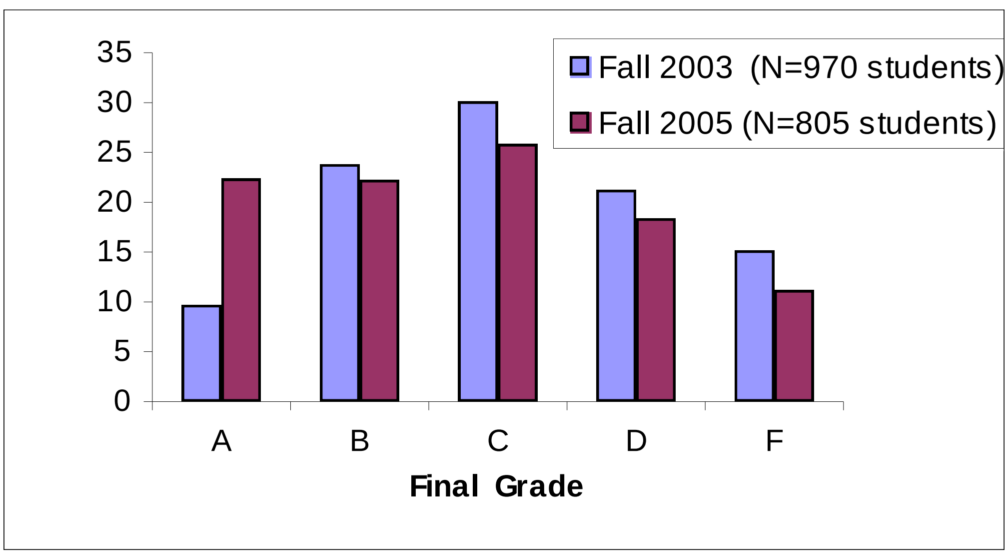

Figure 1. A comparison of grade distributions in pre-FS^2 and post-FS^2 cohorts.

Lab Report Characteristics Relative to FS^2 Intervention

We also assessed the quality of the lab reports. In both the pre- and post-FS^2 years, we asked students to allow us to use their reports (anonymously) to evaluate our program. Not surprisingly, it was usually students with high marks who volunteered their papers. We took a sampling of pre- and post-FS^2 papers that had all received a 90% or above and did an analysis of the two sets of reports. The results are included in Table 2. There are some flaws with this analysis: The formats were such that the pre- and post-FS^2 reports could be identified (i.e., it was not a blind analysis), and the samples were small (14 reports in each group). Nonetheless, the trend was interesting. There was much more variability in the quality of the A^+ pre-FS^2 reports, suggesting that the rubric improved the reliability of the marking. As well, the overall quality of writing improved. Most striking was the students' engagement with their data. Post-FS^2 students wrote more about their interpretation of the data and its significance.

Table 2
Characteristics of Pre- and Post- FS^2 A^+ Reports

PRE-FS^2 lab reports scoring at least 9/10	POST-FS^2 lab reports scoring at least 9/10
• Results sections generally consisted of tables or graphs with/without captions.	• All lab reports provided Results section with a summary of the data: effective use of tables, graphs and statistics.
• Only 5 students attempted to write general trends graphically.	• General trend for data mentioned appropriately in texts and references to the graphs/tables.
• Half the lab reports did not summarize the overall trend of the data.	• All lab reports discussed their points appropriately and seriously in Discussion section and in connection with literature.
• Six lab reports presented the discussion section in point form; one had only a 1/3 page discussion section.	• All but two attempted to account for errors logically.
• Only one attempted to account for errors logically; only one discussed the experiment's strengths and limitations.	• 9 of the 14 reports presented the strengths and limitations of the experiment.
• On a scale of 1-6 for clarity and scientific writing style, lab reports average 2.6.	• On a scale of 1-6 for clarity and writing in a scientific writing style, the lab reports average 4.4.
• Many instances of fragmented sentences and run-on sentences.	• Fewer instances of fragmented sentences and run-on sentences demonstrated; more use of sophisticated sentence structures.

Student Perception of FS^2

Last, we looked at students' perception of the individual FS^2 sessions and analyzed it relative to their performance. For each question in Table 3, we asked students if they thought the particular FS^2 session had been helpful to them. The survey data on student perceptions suggest that students believe that overall FS^2 had improved the quality of their first-year experience. But it was clear that students most valued those sessions that they could directly link to assignment success.

Table 3
Summary of Student Response to FS2 Topics

	Positive response	Neutral response	Negative response	Ratio positive/ negative
University expectations	94	31	47	2.0:1.0
Study strategies	64	42	66	1.0:1.0
Statistical tests	117	28	27	4.0:1.0
Probability in relation to heredity	97	32	43	2.0:1.0
Data presentation	124	22	26	5.0:1.0
Using biology literature	73	42	57	1.0:1.0
Lab report format.	128	15	29	4.0:1.0
Lab report content	118	25	29	4.0:1.0
Critical thinking skills	64	45	63	1.0:1.0
Academic planning	48	57	67	0.7:1.0

Discussion

Developing Effective, Valued Sessions-an Evolving Process

It seems clear from our assessment that FS^2 has improved student learning and perception of their own ability to function as scientists. The success of the program in the fall term biology course has led to the extension of FS^2 sessions into the Introductory Biology Part II, held in the winter term, and so we are beginning the process anew. It is here that we are linking the demands for more sophisticated lab reports to skill sessions for information literacy and research skills, as well as critical reading of the research literature and expanded consideration of data analysis. Given that students register for second year courses in the spring of their first year, we also have created a session that asks students to reflect on their university and career goals, consider their progress toward those goals, and problem-solve around their course selection, cocurricular plans, and academic engagement for the next year.

Helping students to make the transition to university, improve their science literacy, and adopt a research-based approach to their university studies is an ongoing journey for both our students and their teachers (us). We have repeatedly found that the more authentic we can make the learning goals in the course, and the more closely we can align the FS^2 sessions to achieving these goals, the more students value the session. Their valuation is important because students are more motivated to learn actively in class when they perceive that what is being demanded of them is also directly valuable and relevant to their success. Planning and implementing course activities and sessions requires careful co-ordination, and the process by which we continually refine our attempts to facilitate learning is inevitably an iterative one.

Our Collaborative Model: Between “Bolt On” and “Embed”?

The skills that students need to do well in their disciplinary study are the same skills that will allow them to succeed once they complete their undergraduate degrees and pursue advanced degrees or enter the workforce. By carefully integrating skill development with discipline specific course content we avoid any notion that skill acquisition is separate and distinct from disciplinary discourse. Hence we created skill sessions that were integrated into a science course and scaffolded the assignments and activities of the course.

As summarized by Robley, Whittle, and Murdoch-Eaton (2005), the "Bolt On" approach to skill development creates a skill-focused course or workshop series that runs parallel to existing core courses in the disciplines. The perceived advantage is that it can be introduced without altering the content of the core courses, the disadvantage being the potential that generic skill courses may not be discipline relevant and may be perceived as remedial (Wingate, 2007). In the "Embedded" model skill development is learned within core courses. The advantage of this second model is that the required skills are placed in the context of the core course, providing immediate relevancy. The perceived disadvantage is that it requires existing courses to be modified (Robley et al., 2005) and may not get sufficient "buy-in" from course instructors (Wingate, 2007).

Our approach is definitely not classic "bolt on," as we did not create a new, generic skills course. In some measure our approach is not classic "embedded" as the biology content of the course did not change. But we did integrate skill support into the course by adding 10 skill sessions. These sessions are not generic; they are tailored in both language and content to the skill demands of the course. If we were to use an analogy to describe the program it would be that FS^2 has carefully built a scaffold for an existing course to support highly relevant skill development. The advantage and disadvantage of our approach is that it requires a "close-knit" team. The biologists have to take the time to carefully explain their learning goals to the CTL personnel and in doing so have to reflect on those goals and the means to achieve them. The CTL learning experts have to understand how science research and discourse are done and in doing so learn how to better serve that community. To get the project to optimally support students, we have made the additional effort to consult students and understand their perspectives, and annually we must weave the skill sessions into the fabric of the course to support student skill development as the biology content and FS^2 programming continue to evolve.

The collaborative nature of the project, with its shared sense of responsibility and professional development for both the subject experts (course instructors) and skills experts, helps to avoid the potential disadvantages of "bolt on" or "embedded" approaches by providing a discipline-relevant context for improving academic skills that draws on the strength of a range of university personnel. The collaborative approach has the additional benefits of providing content experts with a better perspective on how to optimize learning and provides the learning experts with a better understanding of scientific discourse. Thus the project enriches the course instructors and other learning professionals as well as the community of learners they serve.

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