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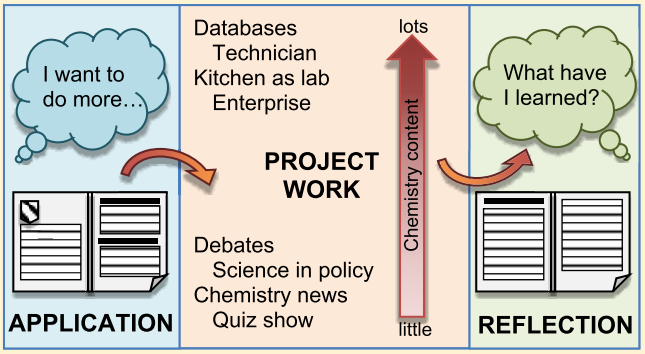
Skills for Success: Student-Focused, Chemistry-Based, Skills-Developing, Open-Ended Project Work

Jennifer Ann Jean Burnham*

University of Sheffield, Sheffield S3 7HF, United Kingdom

Supporting Information

ABSTRACT: Chemistry graduates follow many different career paths. Skills for Success allows students to develop professional skills of relevance to their ambitions by choosing project work from a range varying both in chemistry content and nature of activity. Students apply for a project, do their project, and reflect on what they have learned throughout. This design incentivizes good quality application and personal reflection and allows for ready customization of project work both by students and module conveners. Projects have minimal staff input affording students responsibility for the direction and output of their work. Assessment enables students to perform in application, project, and reflection phases. Students make good use of the choice aspect of Skills for Success. They take responsibility for their work and excel doing so, and they develop critical reflection skills. Student evaluation comments are generally positive and appreciative of the nature of the work.



KEYWORDS: *Upper-Division Undergraduate, Curriculum, Distance Learning/Self Instruction, Problem Solving/Decision Making, Professional Development, Student-Centered Learning*

INTRODUCTION

Skills that are not discipline-specific have been called many things over the years: key skills, transferable skills, generic skills, soft skills, employability skills, workplace skills, professional skills, and intra- and interprofessional skills, and the list will continue to grow. Whatever the term, the skills encompassed are those that are important or valuable in the workplace[1] regardless of whether a job relies on a degree subject or not.[2,3] The call for including wider skills development in a chemistry degree is at least 40 years old.[4,5] Since then, a growing body of work has revealed the importance placed in these skills by students in study,[6−9] and after graduation.[2,3] It has also highlighted a disparity between the content of a chemistry degree and the skills-needs of new graduates in employment,[2,3,10] and it has called for a greater focus on the recognition[1] and development of skills[6,9,11,12] as part of the study of chemistry.[13]

In the UK, most chemistry degree courses are accredited by the Royal Society of Chemistry (RSC) drawing on the Quality Assurance Agency (QAA) subject benchmark statement.[14,15] These require chemistry courses to develop students' professional as well as chemical skills; hence, both types are included in degree curricula nationwide. Professional skills are listed in the graduate attributes a student can expect to acquire during their degree at the University of Sheffield,[16] and the diversity of career paths followed by our chemistry graduates (Figure 1) underlines the need to include them in a course. The question for an educator is how to engineer the curriculum to develop skills as well as teach the subject.

Skills development can be included in a curriculum with training sessions targeting specific skills.[9,18−21] Another way is to use active learning methods, such as context- or problem-based learning,[22,23] enquiry-based learning,[24] and flipped teaching[25] including peer instruction,[26] which develop a wide skills base while students focus on learning their subject.[27] Kee and Ryder suggested students consider their assignments to be of greater importance than the skills used to do them.[18] To mitigate against this, a third way to develop skills in the curriculum is to embed them alongside chemistry teaching[12,28−31] using targeted activities to bring skills to the fore where needed.

A NOVEL APPROACH

The career ambitions of students are not uniform, and so individuals will need customized skills and experience to succeed in a chosen profession. Enabling individuals to tailor skills-development work to their own needs and career ambitions can help avoid problems where "students disengage from activities that seem irrelevant to them".[12] Toward the end of their studies, students should have a reasonable idea of career direction and where development is needed. Given the

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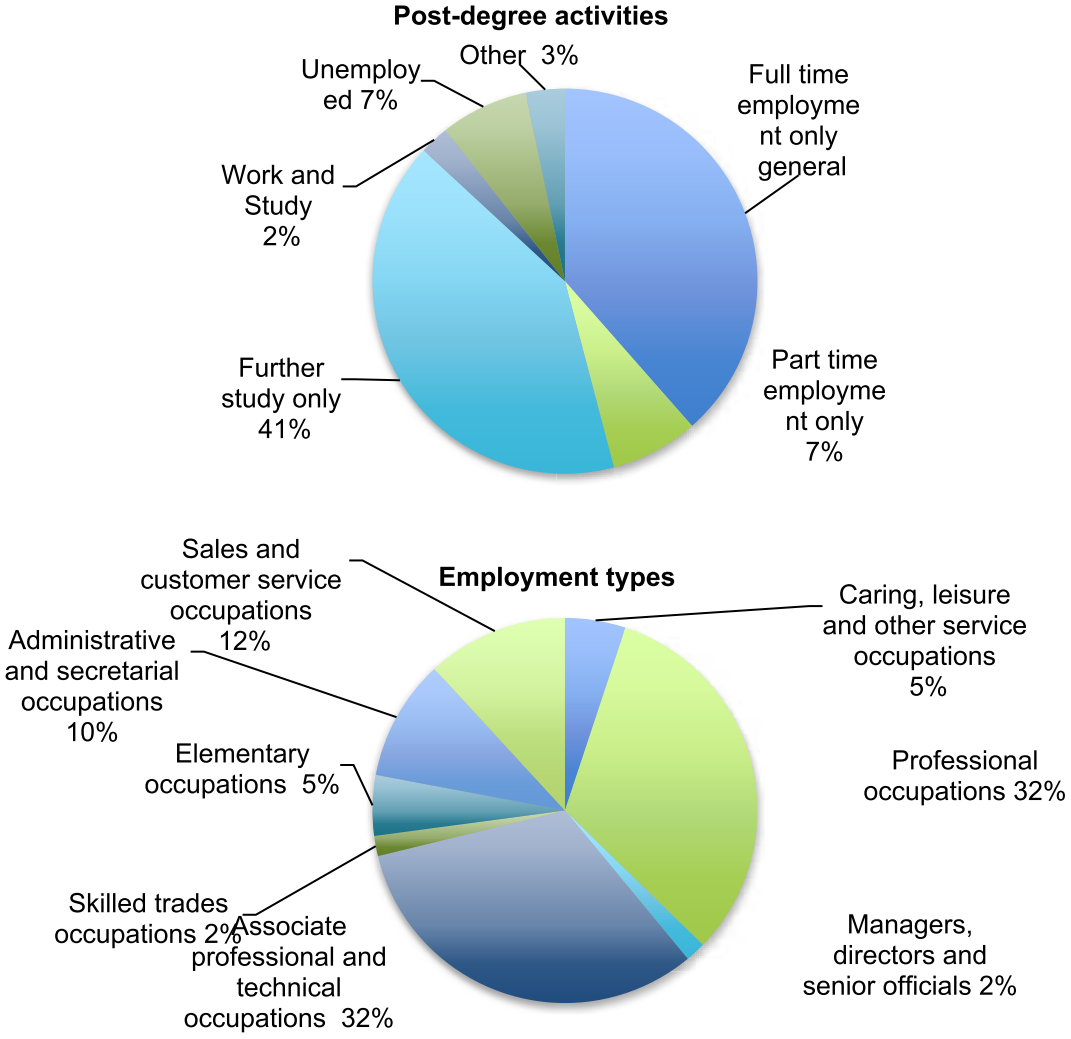

Figure 1. Destinations data for graduates from the University of Sheffield Department of Chemistry 2015−16.[17]

wide range of graduate destinations (Figure 1), it is reasonable to offer options for students to develop skills as they see fit in a similar way that optional modules offer options for students to specialize within a subject. This paper describes Skills for Success: a novel approach in which each student selects project work from a range of activities according to their career ambitions and specific needs and reflects on what they have learned at the end.

THE APPROACH IN ACTION

Skills for Success is skills-based project work in Level 3 (third year, FHEQ Level 6[32]) of the BSc and MChem Chemistry degrees at the University of Sheffield. It consists of three discrete phases: application for a project, completion of a project, and reflection upon the experience (Figure 2). It is 20% of a larger Chemistry Projects module allowing students to take risks and gain experience without compromising the overall module mark. Skills for Success equates to 6 credits (60 h) of study spread through 12 weeks of a semester. Students are encouraged to keep a project journal so that experiences and details are not mislaid alongside other demands of their studies and breaks in the project work.

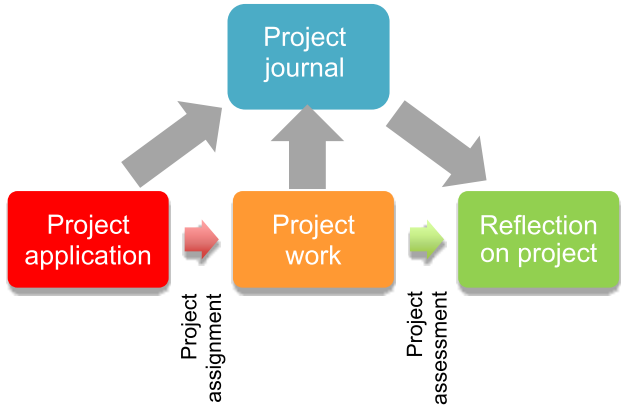

Figure 2. Overall structure of Skills for Success.

APPLICATION PHASE

Skills for Success starts with students applying for their choice of project. Recognition of skills is essential if a graduate is to be successful in securing employment;[1] however anecdotally, students struggle to articulate and provide evidence of their skills and experience[21] so practice is useful. It is hoped that applying for a project will incentivize greater engagement with the exercise than doing a practice CV-application exercise in an

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employment-skills class. The application requires students to outline their experience in a brief CV and answer two typical application questions:

- Why have you chosen this project?
- How do your skills and experience demonstrate your suitability for this project?

Students have 2 days to write their application and are given feedback on its quality by staff allocating the projects.

The application phase is a key part of the module administration as it facilitates project allocation. Students apply for one project and indicate a second and third choice in their application. This means they can be allocated a project that appeals to them, even if their first choice is oversubscribed, which helps ensure they are motivated to engage with their project. The application process is competitive and so it carries no marks. Application quality is judged on the answers to the two questions. The best answers are rewarded with the first choice of project and all students receive feedback on how well they have performed and how to improve. Students who do not submit an application (without reasonable cause) are excluded from the project allocation and receive a mark of zero for the Skills for Success component of the module.

THE PROJECT PHASE

Projects offered vary in nature (Table 1) and amount of chemistry (Table 2), and all are related to chemistry.

Table 1. Projects Grouped by Type and Output

Written Output	Oral Presentation	Other Medium
Group Project		
News Team (magazine)	Debates Project	Quiz show
Enterprise Project		Publicity Team (webpages)
Green Chemistry (new course)		Poster Project (Poster)
Science in Policy (POSTnote)[33]		Video Project
Profile Project		Green Impact (event)
Chemistry-Biology Project		
Individual Project		
Databases Project	Technician Project	Chemistry@Sheffield (infographic)
Chemistry@Sheffield	Kitchen Project	

Inspiration for projects comes from many places including journal articles, conference presentations, the day-to-day experience of the author, suggestions from colleagues, and other identified needs (Table 3). The number of different projects offered has varied year to year as student numbers have fluctuated between 100 and 165 and staff involvement has also varied between 12 and 25 according to need and availability. The projects outlined below are those that have been offered to students. Many others are conceivable, and the ideal project would be one that was proposed by students.

Table 2. Projects Grouped by Amount of Chemistry

Strongly Chemistry-Based	Varying Chemistry Content	Little Chemistry Content
Green Chemistry	News/Media/Publicity/ Poster	Profile Project
Databases Project	Science in Policy	Quiz Show
Chemistry@Sheffield	Video Project	
Technician Project	Debates Project	
Kitchen Project	Green Impact	
Chemistry−Biology Project		

The project phase lasts for 8 weeks with all submissions and deadlines on the Friday of the eighth week. Students are expected to spend between 30 and 40 h on the project including any oral or other assessment. Students' time on the project is fragmented, necessitating good planning and time-management to fit work and group/team meetings around other studies. The project phase culminates in Skillsfest: a timetabled day of activities involving submission and delivery of the assessed parts of the projects when written work is submitted, posters and infographics are put up for display, the quiz show is performed, debates are hosted, oral presentations are given, and videos have their premiere. Students are required to attend a minimum of one event in addition to their own assessment which helps ensure audiences at events and secures the wider impact of students' work. The day finishes with a session introducing the reflection task followed by a reception to celebrate the students' work.

REFLECTION PHASE

Skills for Success culminates in a two-week reflection phase. Reflection is common in many areas of vocational education (see references in Chadwick et al.[31]), but although it has been shown to enhance skills[35] and conceptual development[36] in the laboratory, it can be overlooked in a content-heavy chemistry course.[10] Skills for Success puts aside time for students to critically reflect on their work before writing a reflective essay including both an account and a reflection on what they did. Students need to draw together the fragmented experiences from the project work in order to do a good job of identifying and reflecting on the skills they have used. The reflection essay shows students' emerging self-awareness of their work-related habits and traits, and it has the added benefit of revealing evidence to them of their skills and abilities. Critical reflection can infer self-blame criticism to students new to it. We therefore stress that critical does not mean censure and include a penalty for unbalanced reflection in the mark scheme to motivate students to take a balanced view of their work.

The essay is judged in three parts; communication (how well the essay has been written), an account of what happened, and a reflection on skills development. The assessment rubric is included in the Supporting Information. Essays are submitted to Turnitin[37] primarily for ease of marking and feedback but also to pick out occasional incidences of plagiarism. Initially a limit of 750 words was set to minimize the burden of assessment on staff; however, students and markers found this length too short for a satisfactory account and reflection. Raising the limit to 1,000 words has proven to be a good balance between length and quality.

LEARNING OUTCOMES

By the end of Skills for Success a student will be able to

- Appraise their skills, experience, and attributes, and choose those best suited to the requirements of an employment-style advertisement, using them to complete an employment-style application;
- Demonstrate independence by completing a piece of open-ended project work with minimal direction, individually or as part of a team;

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Table 3. Overview of Projects with Inspiration Attributed

Project	Summary	Inspiration
Contemporary Philosophical Problems in Chemistry (The Debates Project)	Students argue one side in a debate on a contemporary problem in chemistry	White III et al.[29]
The Chemistry Quiz Show Project	Students work as a group to produce a chemistry-based entertainment or quiz show	Student with regular slot on regional radio show
The Technician Project	Students gain work experience alongside the technical staff in the Department of Chemistry	Secondary school work experience placements
Today, the Kitchen Is My Lab	Students learn about the scientific method and apply its principles to a piece of research in their kitchen	Jones[34]
Chemical Databases Project	Students use chemical databases to research a compound and produce a summary of key properties and reactions	Colleague (Prof. Mark Winter)
Chemistry Publicity Team/Chemistry Poster People of Sheffield/Chemistry News Team/Chemistry Media Team	Students work as a group to design and produce attractive and informative posters for display in the department/work with the department's publicity committee/produce a departmental magazine	Colleagues (Prof. Simon Jones, Dr. Ed Warminski, Dr. Grant Hill)
Problems for Chemists (the Enterprise Project)	Students work as a group to write and cost a business proposal	Colleague (Dr. Jim Reid)
Chemistry@Sheffield	Students write a summary and produce an infographic of the research of one staff member	Colleague (Dr. Myles Jones) Infographic idea (Prof. Debbie Gayle Mitchell, BCCE 2016)
The Video Project/Teaching Resource Project	Students work as a group to produce videos for use as additional teaching resources	Meeting presentations (Dr. Paul Taylor, ViCEPHEC 2012 and Dr. Katherine Haxton)
The Green Chemistry/Green Impact Project	Students work as a group to write a course on green chemistry/raise awareness of Green Impact among chemistry undergraduates	"Green Impact" activities in the department
Science in Policy	Students work as a group to research and produce a 3−4 page summary (POSTnote) giving a balanced view of an area of chemistry of relevance to current government policy setting	Colleague (Dr. Liz Baggaley)
The Profile Project	Students work as a group to produce role model studies of careers in academia for the Equality and Diversity Committee	Colleague (Prof. Jane Grasby)
The Chemistry−Biology Degree Interface Project	Students work as a group to research the content and marketing of all chemistry−biology interface degree courses in the UK	Colleague (Prof. Jane Grasby)

- Find and communicate information to one of a range of audience types through one of a variety of written and oral media, using discipline-specific conventions where appropriate;
- Critically reflect on their participation in project work and on their own professional development through the medium of a reflective essay.

Evidence from work submitted shows most students achieve these learning outcomes. The first is addressed in the application phase. Taking 2018−19 as a representative year, 94% of applications cited skills and experience suited for the project applied for. Independence is required by the minimal amount of staff direction during a project, and typically, all students complete their project work by the deadline. The third outcome is assessed in the project output. Examining grades awarded for the project work shows that students overwhelmingly do well, with 89% scoring in the top two grade categories (Figure 3). The fourth outcome is covered by the reflective essay. Skills for Success is the first exercise in critical reflection the students do, so a lower level of achievement by some might be expected. In 2018−19, 81% of essays included some critical reflection; 11% showed evidence of emerging critical reflection skills, and 8% essays displayed neither reflection nor the elements of criticality in reflection.

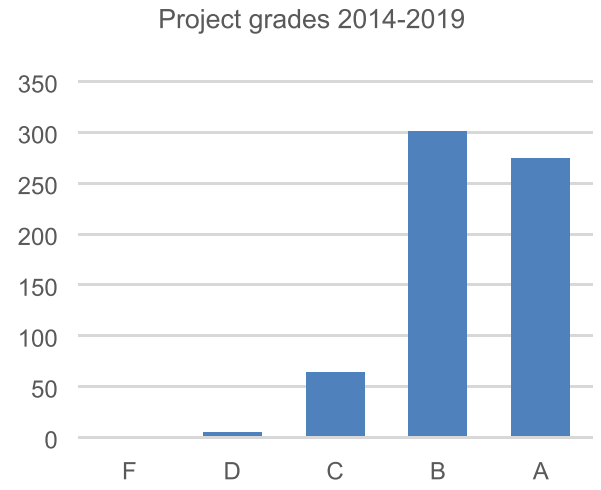

Figure 3. Skills for Success project grades, 2014−19.

■ ASSESSMENT

The Skills for Success assignments are the application, the project output, a project journal, and the reflection essay. The final mark is made up in equal parts of the project output mark and the reflective essay mark. The application is indirectly assessed by the competitive nature of the application process: Good applications are rewarded with first choice of projects and so a numerical score is not deemed necessary. The project journal should be an intensely personal exercise and so journals are not looked at by staff. Good journal-keeping assists the compilation of the project output and provides evidence to enrich the reflection phase. Students often reflect on their journal-keeping experiences either because they are grateful they have kept good records, or because they have realized their mistake in not doing so, thereby self-generating feedback on their efforts.

The nature of the projects is very diverse, and so the assessment criteria for project outputs are derived from the University of Sheffield generic assessment criteria for Level 3 (see Supporting Information). It is recognized that students will use a multitude of skills to get to the output; however,

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students doing the same project may use different approaches and different skills to get there. Because Skills for Success places the importance on the output, the skills assessed are those directly shown therein, and components that have been used in preparing it are not assessed. The Technician project is an exception to this because it includes an element of student performance in the workplace which is a significant part of the project.

Peer assessment is used to reflect individual contributions to the overall success of the group and team projects. Students divide 100 marks among the group for each of three criteria listed below. Results are summed, normalized, and used to moderate 25% of the group mark, and a noncompletion penalty is used to encourage participation.[38]

- Contribution (set tasks): how well each person did the tasks they were allocated
- Contribution (team player): how well each person contributed to the project aims (active participation, assisting others, communicating progress, generating ideas, asking for help at an early stage, etc.)
- Approach to team work: rating each person on their approach and attitude to their group (punctuality, enthusiasm, resilience, attendance, easy to work with, cooperative, etc.)

In the beginning, group projects were awarded a single mark to reflect what happens outside of education. Not unexpectedly, some groups performed well whereas members of others made very different contributions to the work. Peer assessment was introduced in response to student dissatisfaction at the latter situation.

EVALUATION

Applications, reflective essays, and project grades associated with Skills for Success between 2014−15 and 2018−19 were used to evaluate it against its aims. This evaluation was approved by members of the University of Sheffield Research Ethics Committee. The aims of Skills for Success are

- To offer students a choice of project;
- To offer project work that is relevant to students' career ambitions;
- To offer students the opportunity to practice or develop skills;
- To provide a mechanism for students to learn from their experience;
- To give students personal responsibility for completing a piece of work.

Project preferences for five years' worth of projects were analyzed to see if Skills for Success offers a genuine choice of projects. Popularity of all projects varied year by year; however, Kitchen, Databases, Technician, and Chemistry@Sheffield were consistently popular when run, receiving between 10% and 27% of all (first, second, and third) preferences. In the five years analyzed, all projects were selected as first choice by at least three students, and all projects were selected by sufficient students to enable them to run. This suggests the project choice offer is appropriate and is appreciated by students.

Applications for a typical year were analyzed for mention of career ambitions with respect to choice of project. Out of these, 87% exhibited a clear link between career and project confirming the relevance of the Skills for Success offer to individual students' career ambitions.

A typical year's worth of reflective essays showed evidence of students developing skills during Skills for Success and of them learning from experience with 89% reflecting on skills developed and 86% describing learning from the experience or plans for future actions.

Project output marks were analyzed to see how students performed when asked to take responsibility for completing work. Five years' worth of marks were converted to grade bands A, B, C, D, F corresponding to first class, upper second, lower second, third class, and fail on the University of Sheffield assessment scale (Figure 3). Project work was largely of upper second or first class quality, and only one fail mark was awarded in the five years. This shows, definitively, that students performed well with a minimum of direction, and the high proportion of marks (43%) in the highest grade bracket shows that many students excelled.

WHAT THE STUDENTS SAY

Routine module evaluations include free-response comments that afford an impression of the student view of Skills for Success. Many comments are positive. Comments such as "a rare chance" and "refreshing" [to do something different] are reinforced with comments such as "we should do way more projects like this and less exams" and some are effusive in their praise:

> *"I was not excited about the skills for success project when i'd first heard about it, I could not see the point. However I was proven very wrong! The practice in writing applications at the start if the project was invaluable (though I still haven't had any feedback on mine). Also the self reflection activity was quite rewarding to write as i'd not done anything of the sort before. The project itself I found very enjoyable! The technician project really opened my eyes about their workload. The project was really well planned out and run and I never felt like there was anything to complain about"*

Negative student evaluation comments fall into distinct categories. Some view the work as "a waste of time" that could have been better used in subject-based work. Others are uncomfortable with the degree of autonomy ("not a lot of help was provided and reminder about the deadline would have been useful") and hint at problems with insufficient skills "whilst it was supposed to be about developing time management, it was very stressful to have it loom over near the end of the semester". The number of negative comments is outweighed by the number of positive comments, and the overall impression is that students value the experience of Skills for Success and are supportive of its aims and outcomes.

DISCUSSION

Skills for Success is a brief respite for our students from their content-intensive and largely prescribed syllabus because it offers choice, autonomy, and alternative modes of assessment. Typically, staff introduce a project, have one progress meeting, and assess the output. The project work is student-led and open-ended and students have to be resilient, problem solve, and learn how to do things for themselves in order to complete their work. This format maximizes skills-development opportunities for students and minimizes demands on staff. In other project work the students do, all components are assessed and contribute to the final mark. Skills for Success is innovative for

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us in that it has only two assessment points, and some components do not receive a mark at all.

The design of Skills for Success has several strengths: (1) The application process has a very real outcome; therefore. there is a very real incentive for students to engage with it and do a good job. (2) The diversity of projects means there is something for every student. (3) The patchwork nature of projects allows for alteration of some elements without affecting the whole. (4) Skills for Success enables students to undertake work that is of benefit to the department as part of their course. Videos are used as teaching resources; posters decorate and enhance the appearance of the building, and projects such as the Green Impact and Chemistry−Biology Interface projects feed into the wider work of the department.

IMPROVEMENTS AND ADDITIONS

Year on year, we have adapted Skills for Success to improve outcomes, fairness, and the overall student experience. Projects have been tweaked to reduce perceived and actual inequality in effort required, and peer assessment has been included to account for differences in individual contributions. An infographic task was added to the Chemistry@Sheffield projects to challenge students to display information in a creative manner as well as to give them more work to do. The first set of infographics resembled research conference posters with little creativity in imagery and far too much small text. A 100 word limit (excluding references) has been very successful in improving the quality of the infographics which now display information clearly and in a creative manner.

Skillsfest was introduced in part to make the task of scheduling assessment more straightforward and to remove disparity in project end date. On Skillsfest day, the Level 3 timetable is turned over to Skills for Success, and with no other activities timetabled, we are able to require students to attend more than one. Skillsfest also provides an excellent excuse for a party. Many of our students graduate with a BSc at the end of Level 3 and hence miss out on the party held at the culmination of the Level 4 research projects. This inequity is wrong and Skillsfest helps resolve it.

CONCLUDING REMARKS

Students doing our courses receive an education that satisfies a broad range of learning outcomes. Skills for Success allows them to spend more time honing skills to suit their career ambitions in addition to gaining practice in completing application forms and develop self-reflection skills. It can be thought of as skills-enhancement because although students have the opportunity to develop each skill elsewhere in their degree, they improve them in Skills for Success. Every year, the reflective essays contain evidence of the benefits felt by students: Some improve skills, some gain confidence, and nearly all reflect on how they might use what they have learned in the future. More than one student has said their Skills project helped them determine their career direction, for example, into pursuing masters-level study they would not have considered beforehand.

Over seven years, the three-phase framework for Skills for Success has proven to be a robust scaffold for the portfolio of project work and has required only minor changes to improve the student experience and streamline administration. Skills for Success has enabled the department to invest emotionally in the graduating BSc class. Before Skills for Success, BSc students quietly slipped out of the department at graduation. Now, there is a buzz around Skills for Success projects culminating in Skillsfest where staff and students come together to celebrate their achievements.

Skills for Success is having a deeper paradigm-shift within the department. By not assessing applications and project journals, and by allowing students ownership and almost free rein on their project work, Skills for Success has allowed staff to temporarily step away from instructor-led teaching. This has opened up the possibility of students engaging with and being engaged more in departmental life. For example, the success of the original Chemistry News project led to the creation of a student-led departmental magazine which continues to publish twice yearly and whose editorial board and contributors come from across the undergraduate and postgraduate student population.[39]

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00513.

- Skills for Success application form (PDF, RTF)
- Skills for Success projects descriptions (PDF, DOCX)
- Skills for Success project assessment criteria (PDF, DOCX)
- Skills for Success reflection activity guidance (PDF, DOCX)
- Skills for success reflection assessment rubric (XLSX)
- Peer assessment calculator spreadsheet (XLSX)

AUTHOR INFORMATION

Corresponding Author

*E-mail: j.burnham@sheffield.ac.uk.

ORCID

Jennifer Ann Jean Burnham: 0000-0001-7448-7470

Notes

The author declares no competing financial interest.

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