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Summer Research Placements – State-of-the-Art Science by pre-University Students

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ABSTRACT

Summer research placements are an effective training and research tool. Over three years, our group has hosted nine pre-university students over periods of four to six weeks. Apart from student training and skills acquisition, the placements have produced several peer-reviewed technical publications. Our approach relies on careful pre-planning of activities, frequent student interaction, coupled with independent and group learning. We explore the advantages and disadvantages of this manner of running summer placements.

INTRODUCTION

It has been recognized for some time that there are significant shortcomings to the preparedness of UK pre-university students for undergraduate degrees in STEM subject areas [1]. This is due, to some extent, to the apparent disconnect between the disparate Science subjects taught in school and the continuum of notions required in Engineering, Electronics and Materials in particular: Chemistry, Physics, Mathematics, Computer Programming, etc. [2].

Here we discuss lessons learnt during a series of small scale summer research placements in our Institute, and reflect on the applicability of our conclusions to the general pre-university student population. Essential to our approach was the focus on discipline and planning: introductory “meet your supervisor” sessions prepared students for the expectations of the project well in advance; most students worked with a “project buddy” to lessen the reliance on the supervisor’s input; for effective implementation, projects were designed ahead of time to be self-contained, manageable during the time frame and accessible to gifted pre-university students.

ACTIVITY DESCRIPTION

Context

UK Organizations such as the Nuffield Foundation and SATRO have been offering summer research placement for some time [3, 4]. Host organizations such as university research centers, clinical facilities and engineering firms volunteer to host pre-university students, usually 17 year-olds, for a period of four to six weeks over summer. The projects can stem either from a student’s “research proposal”, in which case they are driven by the student’s desire to study or optimize a particular problem, or from a genuine item of research or development already identified by the host. The majority of the projects are in Science, Technology, Engineering, Mathematics and Medicine (STEMM).

Students are nominated by their teachers and fill in an application which includes a personal statement, their academic performance and interests, and a reference from the teacher. The applications are paired with the available hosts and projects to ensure a good match. Ultimately, the selection decision rests with the project supervisor at the host institution, but may be complicated by mutual availability of students and supervisors over summer.

Student profile

The scheme is open to applicants interested in STEM subjects who are one year away from University enrolment. In the case of our Institute, students' career preferences have ranged from Theoretical Physics and Philosophy of Science to Chemical Engineering and Nanoscience. Interestingly, very few, if any have been directly interested in our major research themes such as Nano-electronic Devices, Energy, or Material Science.

Learning strategies and program management

The placement is conducted on site in a contiguous period of approximately four weeks. An early summer "meet your supervisor" session gives students a chance to familiarize themselves with the surroundings through a short visit which includes an overview of the project, lab tours, and questions and answers [5]. It is also an opportunity to present students with new notions, to highlight the impact and applications of their future work, and to assign background reading. This whets the appetite for the project and gives students something to look forward to during the following exam period.

The projects are always individual, but a variety of collaborative strategies have been trialed, from fully independent work to group study. We assigned a "project buddy" whereby each student is in charge of his or her own project, but is also tasked to help another with theirs [6]. In practice we have found that all students collaborated and helped each other disregarding these artificial divisions between projects.

Central to the way our group ran these projects was the focus on learning engineering concepts and good practice and the real-life experience. To this end, the projects chosen were genuine pieces of research, adapted to be accessible, self-contained, and manageable within the timeframe. While the quality of the work depended somewhat to the understanding of very specific technical notions, it was recognized that these may not be relevant to the students' future career. We attempted to develop (in the first instance, awareness of) a wide range of skills necessary for a successful engineering or research career and included activities to target:

- Experimental methods;
- Errors and uncertainty;
- Numerical methods and limitations;
- Safe operation;
- Data processing and presentation;
- Time management;
- Project management;
- Group and solitary work;
- Scientific writing: mock conference abstract and structure of scientific paper;
- Writing for a lay audience: mock press release or news item;
- Oral presentation to a technical audience;
- Visual presentation in various formats: poster, print and slides;

- Non-technical audience interaction around their poster.

Students were asked to prepare a detailed report of their activities, including personal reflection, which qualifies them for a Gold Crest Award. This report included a selection of the real research data and methods chosen to demonstrate progress without revealing publishable data.

The timeline of the projects consisted of:

- An initial setup meeting (2h) two months ahead of the placement, as described above;
- One day of induction, health and safety and administrative tasks (e.g. log in details);
- Three days of undergraduate-style teaching of the technical material and familiarization with the software environment;
- Two-three weeks of experiments (usually computer modelling and simulation of advanced semiconductor structures, rarely assisting with fabrication of test structures in the clean room);
- One week for data processing and interpretation, technical and non-technical writing, report draft;
- Presentation of draft posters as slides to a technical audience (Institute seminar);
- Presentation of posters to non-technical guests during award evening.

DISCUSSION

It is important to emphasize that the principal purpose of the placements as set out by the organizers (SATRO, Nuffield) is to offer students hands-on training on skills which they are likely to use in their future careers. This could easily be achieved by allowing them to shadow a researcher or to go through a nominal piece of simulated research. A variety of projects of this nature are run routinely in most organizations, but most often they provide for students exposure to the research without ownership.

Our intention was more specific: to create a deep understanding [7] of the research process, while conducting genuine, publishable research. For this reason, experiments and timelines had to be planned with great care ahead of time, and a parallel between these small-scale intensive projects and PhD courses can be drawn. Both endeavors:

- require taught elements and self-learning, which is challenging [8];
- are concerned chiefly with a self-contained piece of research, with hard deadlines and expected milestones;
- involve similar responsibilities from the student and the supervisor, and have the expectation of a certain quality of output;
- contain some degree of unpredictability, surprising research results, and of course, tedious, repetitive actions;
- have the expectation of personal growth and developing multiple facets alongside the specific technical expertise.

All of the above make this type of summer research placement an accurate simulation of real-world research, both for the student and the supervisor. This is the main point of originality for our approach.

Emphasis was placed, naturally, on the learning experience of the students and on research quality. Students appear to have treated their opportunity as more than a summer job, and this

was aided by the “cool factor” associated with using bespoke machinery and high performance computers, and with a leading educational institution.

Measures of success include student satisfaction, student admission to desired university assisted by the improved personal statement, exam performance or CV following the placement, peer-reviewed publications, increased confidence in teaching for supervisors, development of new teaching materials and techniques, follow-on public engagement activities with placement student participation, and even increased number of applications for future placements or degrees at the host institution.

Placements appear to have been very successful, particularly given the fairly short duration, giving students the means of applying for a Gold Crest Award [11], to enhance their University application personal statement, and to gain an understanding of the opportunities, challenges and general reality of research. Students reported an enhanced understanding of both the research journey and the technical topic, and were able to make more informed choices concerning future university options and courses.

A significant outcome has been the generation of new Applied Physics research data, either published [9, 10] or being submitted to highly-respected, peer-reviewed conferences and journals. Skills developed include:

- working independently and with others, both peers and more experienced ‘experts’;
- learning and applying research methods and technical expertise;
- research project planning, data analysis and presentation;
- scientific writing;
- communicating research findings to the public.

At the same time, the placements were used as a testing ground for teaching techniques and research group management practices; useful to a junior researcher aspiring towards an academic career.

The following strengths – opportunities – weaknesses – threats (SWOT) analysis highlights the value of the scheme to various interested parties, as well as the limitations and shortcomings of the scheme as is.

Strengths

- Boost to placement student confidence, range of skills and personal statement for university applications;
- Integration of learning from disparate STEM(M) subject and understanding of the relationships and interdependence between these subjects in practical engineering and research.
- High-quality publishable research results;
- Local media (and sometimes international press) coverage of work, targeting both the importance of the research results and the merits of the young researchers;
- Increase the reputation of the Institute and University (or generally, the host institution) among school students, teachers, parents and local community;
- All of the above raise awareness of and enthusiasms for STEMM careers and education opportunities.
- Greater understanding of the level of knowledge and approaches to pre-university learning

Opportunities

- Effective means of testing out small group teaching techniques, especially useful for research staff with limited teaching experience;
- Innovation of teaching techniques at undergraduate level;
- Simulation of postgraduate research student group dynamic;
- Dialogue and engagement with local and national authorities. The placements serve as a demonstrator for possibilities in both STEMM education and careers, inviting debate with policy makers, educators, parents, etc.

Weaknesses

- Gender participation: all of our placement students so far have been young men; a single female applicant decided to decline the placement. This has been recognized as a common problem in STEM and one that needs to be addressed in earlier age groups [12];
- Health and safety considerations: our placements have been almost exclusively concerned with computer modelling and simulation; lab work may involve elaborate paperwork and training, which may make the whole placement less attractive for the provider institution (risk), supervisor (paperwork and organization) placement student (tedium);
- Similarly, working with minors is governed by certain rules which complicate the setting up of such activities. For example, in the UK, all persons with whom the minor placement student interacts on a one-to-one basis need to undergo a Disclosure and Barring Service (DBS) check [13] prior to commencement of activities.
- Consumable costs, software license availability and publication costs need to be provisioned by the provider;
- Scalability: it may be impractical to increase the number of students per provider without significant change to the way the scheme is approached and funded. Equally, finding many more suitable providers/hosts at a national level may prove challenging.
- The scheme does not directly target disadvantaged students. Placements are awarded on academic merit and practical considerations (distance to travel, availability over summer), but arguably this provides training to students who already have significant future opportunities resulting from their existing track record;
- Time: the placement is short for a research project but long in terms of commitment from the supervisor. It also takes place during summer holiday, suggesting that supervisors able to commit may be hard to come by, despite their overall enthusiasm regarding the scheme;
- Distance: by its nature, the scheme only works if the student lives within reasonable distance of the host institution. This limits the practical matches which can be made. As an extreme, distance may cause a student to decline an otherwise ideal placement;
- Our approach and relative success with the scheme may not be translated directly to other disciplines, even within STEMM.

Threats

- Not enough “exploitation” of opportunities above. Some prior effort and planning is required to design dissemination and engagement strategy for maximum impact;
- Uncertainty in the long-term support of this and similar schemes by the organizing charities.

CONCLUSIONS

Summer research placements open to pre-university students are an efficient way of simultaneously training a small number of students and generating significant research results.

Central to the success of the approach are: the careful prior planning while allowing for unforeseen setbacks, the continuous student interaction, and the design of manageable and self-contained projects. All of these factors ensure placement student buy-in and allow the generation of meaningful research results while immersing students in the reality of scientific research. Ultimately, through their newfound understanding, students become advocates of Science and Engineering and ambassadors for both the field and the host institutions.

Hosting such placements, is not always practical, especially considering the contact time that has to be devoted, health and safety, mobility and accessibility, and work with minors.

Applied Science and Engineering disciplines may find adapting this type of placement relatively trouble-free, as long as the placement is treated as an intensive, combined teaching and research stage, which requires adequate planning as well as constant student interaction. While translating this approach directly to larger cohorts with a wide spread of ability is not simple, the learning gained from these projects could inform the development of more efficient engineering educational activities for pre-university students.

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