

Evolution of the 3rd Year Physics Major Project at WITS

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Abstract. The Major Project has been an important component of the 3rd Year Physics curriculum at WITS for many decades. It has proven very popular with the students and has allowed academic staff to identify students with research potential as early as the final year undergraduate level. In the original model each student chose a project offered by a member of the academic staff, and completed the work required during one of the first three quarters of the academic year. In 2015 the student numbers increased dramatically from approximately 25 students to approximately 50 students, and it became increasingly difficult to run the projects in their existing form. In 2018 the major project underwent a transformation, and since then students have completed an Independent Research Essay (IRE) under supervision of a member of the academic staff, with a student teaching assistant acting as a mentor for a small group of students. This report provides a description of the evolution of the Major Project, paying particular attention to the components of the IRE as it is at present. In particular, it will be shown how the IRE may be used to inculcate or enhance essential skills for budding scientists, be they enrolled students or graduate student tutors.

1. Introduction

The final year physics undergraduate curriculum in institutions of higher learning should be designed to equip students with sufficient background to proceed to post-graduate study, and should also take note of the number of students that will not continue with their studies following successful completion of a bachelor's degree. Examination of the literature in Physics Education Research (PER) shows that the vast majority of studies are aimed at addressing teaching and learning at first year level. This is understandable, as students in the first year of study often arrive from secondary schooling with critical misconceptions that hamper their ability to succeed at tertiary level. While PER studies of higher-level courses are rare, studies that focus on laboratory curricula are even less common. In the recent past, reports by Zwickl *et al* [1, 2] have attempted to provide laboratory coordinators with guidance as to the design and implementation of innovative higher-level laboratory programmes.

A description of the Physics III curriculum at WITS has been provided previously [3]. In brief, the curriculum comprises five modules, for a total of 72 points (this a standard points allocation for a 3rd Year course at WITS). There are four modules that are presented by way of lectures (11 points each), and the Advanced Experimental Physics and Project (PHYS3006) module which is worth 28 points. At present there are three components of the module: Set Experiments, An Introduction to Electronics, and the Major Project. The Major Project contributes approximately 50% of the final mark for the module. This activity therefore contributes a significant portion of the final mark for Physics III. Moreover, the activity has always been extremely popular with the students, who have cited it as the most stimulating component of PHYS3006 in several course surveys over the years [3]. Any changes

that are made to the format of the Major Project should not negatively affect the existing learning goals and outcomes of the activity. Any implemented changes should also be designed to enhance the skills required for graduating students who are proceeding to post-graduate study, and those who will be making their way into the workforce [1].

This report seeks to provide the reader with a description of the evolution of the Major Project component of PHYS3006 for the period 2011-2021. While it is clear that the initial impetus for considering and implementing changes is the remarkable increase in student numbers (see Fig. 1), it will be shown that the changes that were made provide the students with the opportunity to develop certain high-level skills that will benefit their future careers. The opportunity for the teaching assistants, who support small groups of students, to develop supervision skills, is a useful by-product of the changes that were made to the Major Project.

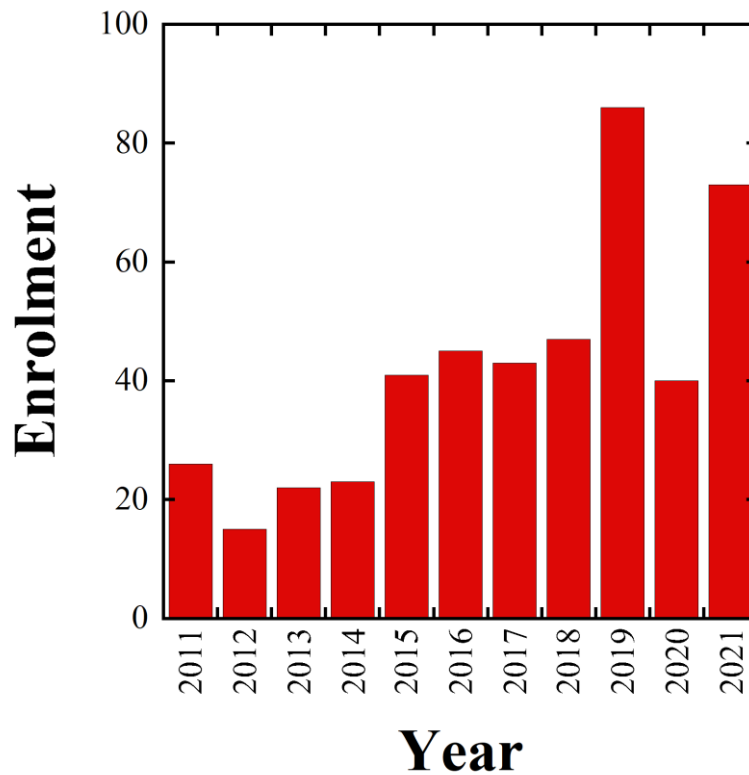


Figure 1. Student enrolment for PHYS3006 for the period 2011 – 2021. This corresponds to the period for which the author was the coordinator of the PHYS3006 module. The data show that for the period prior to 2015 student numbers were stable at approximately 25 students. A sudden increase in student enrolment for the period 2015 – 2017 placed severe strain on the existing model for the Major Project (see Section 2.), and changes were implemented for 2018 and subsequent years. The Independent Research Essay was introduced and is described in detail in Section 3 of this report.

2. The Physics III Major Project prior to 2018

The Major Project has been described in some detail previously [3]. Fig. 2 shows a flow diagram of the Major Project, which indicates that the student and supervisor are in essentially a one-to-one relationship for the duration of the project. Some members of the academic staff were able to rely on a cohort of graduate students that were under their supervision to assist with 3rd Year project supervision, but this was by no means the case for all supervisors. The activity was designed to develop the following essential scientific skills: critical reading of scientific literature, written and oral communication, and the ability to develop analytical thinking. Students were introduced to some of

the research interests of the academic staff in the School of Physics, albeit in projects that were designed to be didactic, rather than directly related to the supervisor's research programme. As was pointed out in the Introduction, students reported that the activity stimulated their interest in physics, and it was rated as the most valuable part of PHYS3006 by a majority of students in formal course surveys.

The increase in student numbers, which was first seen in 2015, placed increased pressure on supervisors and their research groups. From having to supervise one project per year, they were now being asked to supervise two or three projects. The inevitable result was "supervisor fatigue", and the activity was no longer a pleasurable experience for the research-active academic staff. It was clear that the Major Project could not continue in its present model, and alternative activities were considered.

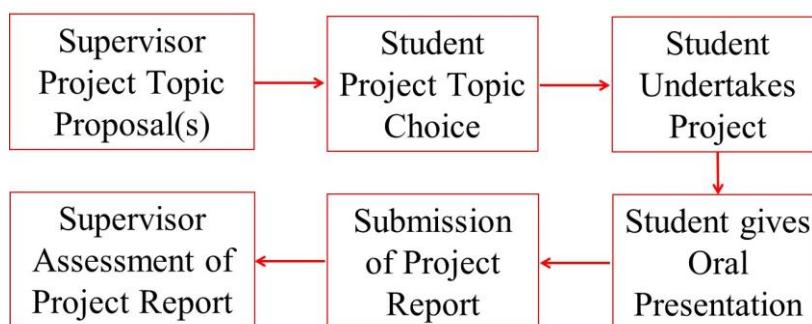


Figure 2. A flow diagram for the Major Project for the period 2011 – 2017. Further detail is provided in Section 2. As can be seen, this model is dependent on a one-to-one relationship between the supervisor and the student. With the approximately two-fold increase in student numbers first encountered in 2015, offering the Major Project in this form became increasingly onerous for supervisors. The Independent Research Essay was introduced in 2018.

3. The Independent Research Essay (IRE)

The coordinator of the module was reluctant to replace the Major Project with alternative activities. Firstly, it was clear that the essential skills that the project was able to inculcate could not be imparted by some of the suggestions that were made. A proposal for an Independent Research Essay (IRE) was prepared and presented to the School of Physics Teaching and Learning Committee, and this was accepted for implementation in 2018. The activity was designed to retain many of the desirable aspects of the previous model for the project, but to ensure that the aforementioned "supervisor fatigue" was minimized. While the IRE runs throughout the year, the contact time required from the supervisor, even if more than one essay is supervised, is designed to be less than, or equivalent to, supervision of an experimental, computational, or theoretical project. To this end, responsibilities were devolved from the supervisor to teaching assistants. For the purposes of the activity, the job description of the teaching assistants is Essay Tutor. Each tutor was allocated a small group of students (between five and ten) and asked to act as mentors. Details of the responsibilities of supervisors and essay tutors are provided below.

A flow diagram of the IRE is shown in Fig. 3. It is immediately obvious that continuous assessment is part of the model, as each student is required to submit a minimum of two and a maximum of three documents for assessment, in addition to the assessment of their oral presentation (known as the Oral Defence in this case). Readers that are familiar with the procedures for Higher Degrees will notice that the activity is designed to introduce the 3rd Year students to the scientific process of doing research. Each student is required to prepare a Research Proposal, which must contain a Literature Review and a Work Plan. More details of this phase of the IRE are provided below. It is recommended to the students that they submit both a First Draft and a Final Draft of the

IRE, so that they can respond to the comments made by the supervisor on the First Draft. Some students decide to only submit a First Draft, or only to submit a Final Draft.

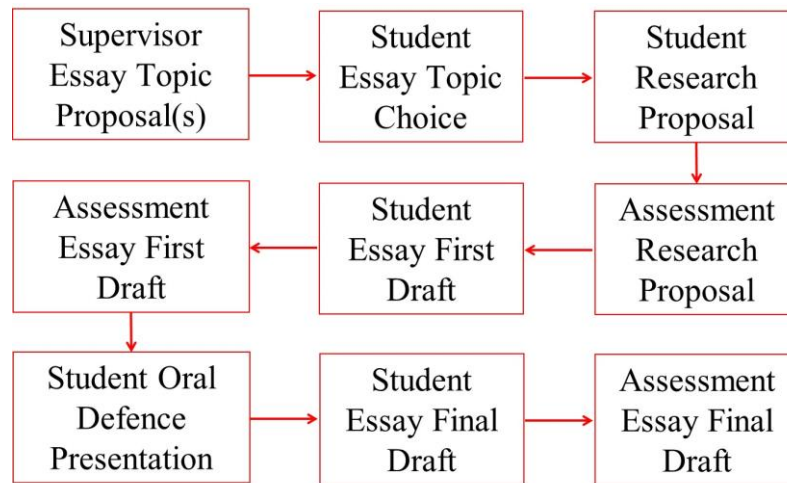


Figure 2. A flow diagram for the Major Project for the period 2018 – 2021. Further detail is provided in Section 3. In this model the time demands on supervisors are significantly reduced. Much of the day-to-day support is provided by the essay tutors. The essay tutors benefit by learning how to supervise a small group of students.

3.1. Supervisor Essay Topic Proposals

Every research-active member of the academic staff is required to submit at least one Essay Topic Proposal. It is suggested that the essay topic be sufficiently broad so that more than one distinct essay is possible (for example, the broad title of “Superconductivity” will allow the supervisor to offer several distinct essays). The proposal consists of supervisor details, a short synopsis of the essay as envisaged by the supervisor, and a short list of readily accessible introductory reading references. These proposals are posted on the Learning Management System web page for PHYS3006.

3.2. Student Essay Topic Choice

Students are divided into three groups. Each group receives a tailored list of prospective supervisors and their proposed essay topics. Students are required to make a shortlist of essay topics that interest them, and to make (and attend) appointments to meet with at least three potential supervisors before making their final choice of topic. The final choice is signed off by both the student and the supervisor.

3.3. Research Proposal: preparation and assessment

Supervisors are requested to provide additional references (if necessary) once they have accepted a student for supervision. The student is expected to use the reading suggested to seek additional references, and to prepare a Research Proposal of six pages which includes a Literature Review and a Work Plan. The final document must go through plagiarism detection software before it is submitted to an online submission portal. A rubric for assessment is provided to both the student body, and the supervisors. The Essay Tutors assist their group of students throughout this process, meeting once a week with their group. Their role is to mentor the students, to ensure that the students are making reasonable progress, to provide electronic copies of references, and to assist with referencing style and other presentation issues. Supervisors are only consulted by their student if scientific understanding issues arise, and the students are required to make an appointment if they need to consult their supervisor.

3.4. Student Oral Defence Presentation: preparation and assessment

Approximately three weeks before the date of the Oral Defence the students attend a session that provides them with tips and suggestions for the preparation and delivery of a successful Oral Defence. Each presentation is limited to 15 minutes, which includes 3 minutes for questions. Essay tutors ensure that their small group of students has at least one practice run before their presentation. The number of enrolled students has meant that the presentations are given in several parallel sessions, with the supervisors, the essay tutors, and the relevant small group of students in attendance. The essay tutors chair one half of each these sessions, and so gain session chair experience. Every person attending an oral presentation is required to assess the presentations according to a simple rubric. The policy at present is to take the average of the peer assessors, the average of the instructor assessors, and for the final mark to be the average of those two.

3.5. First and Final Draft: preparation and assessment

The student is expected to use their Research Proposal, and the comments made by their supervisor on the proposal, to do additional reading and research. The results of the reading, research, and writing will be the First (or Final) Draft of the essay. The final document, which should be between 20 and 30 typewritten pages, must go through plagiarism detection software before it is submitted to an online submission portal. A rubric for assessment is provided to both the student body, and the supervisors. The Essay Tutors assist their group of students throughout this process as before. The responsibilities of the essay tutors and supervisors are essentially the same as for the Research Proposal phase of the IRE. If a student decides to submit a First Draft, then they may use the feedback provided by their supervisor to improve the document and submit a Final Draft, or they may decide that they will accept the mark for the First Draft as their Final Draft mark.

4. Conclusion

A precipitous increase in student numbers has persuaded the School of Physics at WITS to review the model for the Physics III Major Project that has been in use for decades. The previous model required a large time commitment from research-active academic staff members during the duration of the project. In the past this was concentrated in one quarter of the academic year, but the increased numbers meant that this commitment was extending to two, and even three quarters in some cases.

A model involving an Independent Research Essay (IRE) was introduced in 2018. The IRE is intended to retain some of the best characteristics of the previous model, including an oral presentation and final written submission. In addition, the IRE allows for a continuous assessment of a student's written skills. The process goes through stages that mimic the development of a real research project (proposal, two drafts, oral presentation), and therefore provide skills that are useful to all early-career scientists.

The introduction of teaching assistants into the project, with the title of essay tutor, greatly reduces the time demands on the essay supervisor. This also allows the teaching assistant to gain invaluable experience of the process of successful supervision.

The previous Major Project model allowed students to encounter experimental apparatus, or a computational model, or a theoretical calculation. This experience cannot be offered using the IRE model, but the additional positive aspects of the IRE model are fair recompense for the lost experience.

References

- [1] Zwickl B M, Finkelstein N and Lewandowski H J 2012 *Am. J. Phys.* **81** 63-70
- [2] Zwickl B M, Finkelstein N and Lewandowski H J 2012 *AIP Conf. Proc.* **1413** 391-394
- [3] Kearthland J M 2014, *Proceedings of SAIP2012: the 57th Annual Conference of the South African Institute of Physics* 412-417 ISBN: 978 1-77592-070-0