TRINITY COLLEGE DUBLIN

PROVOST'S REPORT TO COUNCIL ON THE REVIEW OF THE SCHOOL OF PHYSICS

1. INTRODUCTION

This report presents the outcome of a review of the School of Physics. An external peer review visitation was undertaken from the 20th – 21st March 2012 by Prof. Christine T.H. Davies, University of Glasgow, UK; Prof. Margaret M. Murnane, University of Colorado at Boulder, USA and Prof. László Forró, École Polytechnique Fédérale de Lausanne, Switzerland. The internal facilitator was Mr Bruce Misstear, Trinity College Dublin.

The report is based on (i) feedback from the External Reviewers received on the 25th May 2012, (ii) a submission from the School of Physics received on the 5th June 2012 and (iii) a submission from the Dean of Engineering, Mathematics & Science received on the 6th June 2012.

The main purpose of the School review is (a) to provide a structured opportunity for the School to reflect on its activities and plans for development, while benefiting from a constructive commentary by senior colleagues external to College; (b) to ensure that quality and standards in teaching, research and administration are being maintained and enhanced and that areas of concern in this regard are identified and addressed. Each School in College is reviewed systematically once every seven years.

2. OVERVIEW OF THE SCHOOL

2.1 Aims and Objectives of the School

The School of Physics was formed from the previous Department of Physics in 2005 and has a long history of teaching and research dating from the 1700s. The School is part of the Faculty of Engineering, Mathematics and Science and its mission is to teach physics to undergraduate and postgraduate students so that they become competent and confident scientists who will help build a better society and carry out research to develop new knowledge and understanding of the natural world. The School aims to promote a culture of excellence in research and to support research both at the individual level and on a collaborative basis within the envelope of academic freedom. In particular, the School wishes to foster research and scholarship that is of an international standard and published as journal articles, books or in other scholarly media. It is the aim of the School that some of its research be relevant to the current and anticipated needs of society and that appropriate engagement with civil society be encouraged. Undergraduate education is also a key priority in terms of the activities of the School of Physics. Its graduates are of great value to Ireland's knowledge-driven economy, many of whom provide a valuable resource in terms of

recruitment of able postgraduate students for research in the School of Physics and CRANN (Centre for Research on Adaptive Nanostructures and Nanodevices).

2.2 Programmes to which the School provides teaching

Undergraduate:
The School of Physics provides Freshman modules within the *TR071 Science* course, with Sophister options in Physics and in Physics and Astrophysics. The School also contributes to the direct-entry degree courses *TR035 (Theoretical Physics)* and *TR076 (Nanoscience, Physics and Chemistry of Advanced Materials)* and provides a small number of modules to non-physics students, e.g. physics for JF engineers (PY1E04), physics for physiotherapists (PY1P01 & PY1P02), physics for earth scientists (PY2P30) and physics for health sciences (PY1DR1).

2.3 Research

There are currently 110 postgraduate students in the School with numbers rising steadily since 2004, against international trends. The School has been one of the largest research income earners in College in the period 2001-2011. Several major research groups funded by Science Foundation Ireland (SFI) to conduct cutting-edge research into information and communications technology are now integrated into the School and CRANN. This has led to increasing international recognition in recent years. Inventions and technical developments originating in Physics laboratories have led to the foundation of several campus and spin-off companies. The School has a worldwide reputation in several fields, including magnetism and magnetic materials, electronic and photonic materials, nanoscience, foam physics and computational physics and it also has an increasing reputation as a centre for astrophysics research.

2.4 Summary Statistical Profile of the School for the Academic Year 2010/11[1]

Full-time Staff FTE	Undergraduate FTE	Postgraduate FTE	School Staff: Student Ratio	Faculty Staff: Student Ratio
26	**185**	**96**	**11**	**15**

Figures from Senior Lecturer's Annual Report approved by Council at its meeting on 15th February 2012

2.5 Accommodation and Facilities (Physical Resources)

The School of Physics currently occupies the Fitzgerald building, large sections of the CRANN and SNIAM buildings, and a small part of the Lloyd building. Research groups also occupy a small number of offices in numbers 12, 13, 14 and 22 Westland Row. Each member of the academic staff is furnished with their own office, with most technical and other support staff sharing office or workshop space. There are no plans to increase the School's accommodation at present. There is one social space in the Fitzgerald Building.

[1] *The staff FTEs include all Professors, Associate Professors, Senior Lecturers and Lecturers funded from the core HEA grant, or from self-financing courses, and all part-time and occasional staff and demonstrators, converted to an FTE, who are funded from core grant or from self-financing courses.*

3. REVIEWERS' RECOMMENDATIONS

The Reviewers make the following major recommendations:

3.1. To attract more female students and faculty into physics, the School should engage with the Institute of Physics Juno award programme. This has been very successful in the UK in establishing best practices around education and hiring. Attracting more female students and faculty should be a priority given worldwide trends in college education.

3.2. Although the quality of the undergraduate programme is excellent, there needs to be continuous improvement to attract the best students, and particularly to attract international students. A key degree with a lot of potential that is not being adequately fostered by the school at present is the theoretical physics degree. The Reviewers recommend that a joint committee with mathematics is set up to revisit the curriculum and the provision for students in this degree.

3.3. A more proactive approach to teaching innovation and curriculum development is needed from the Teaching and Learning Committee. The Reviewers also believe that staff-student liaison with respect to teaching and learning needs to be improved.

3.4. The Reviewers recommend that the training and mentoring of postgraduate students should be improved, for example by the routine allocation of a second supervisor. This person could provide more general advice/encouragement for students to develop transferable skills. The training of postgraduate students (and postdoctoral researchers) in teaching techniques is very important both for their career development and for the undergraduate students in their care. This needs to be taken more seriously by the school, since the standards for effective teaching required to compete internationally are rising. More creative use of postgraduate students and postdoctoral researchers in teaching by allowing them to choose a contribution, for example in tutorials or project work instead of laboratory demonstrating, could help to improve their motivation.

3.5. To maintain scientific leadership, the Reviewers recommend that the College and the School should work together to hire a world-class faculty member when Prof. Michael Coey retires. There may also be an increasing need to retain other strong faculty, as is the case with all world-class departments.

3.6. The Reviewers recommend that it would be worthwhile to consider implementing a performance and development review system, to encourage all faculty to contribute and to encourage innovation at all levels (teaching, research, service and outreach). Most faculty can excel at only two of these activities simultaneously, and the distribution may change over time. However, metrics that encourage all faculty to ask how they can contribute to improving the School and College would be good for everyone.

The Reviewers make the following minor recommendations:

3.7 In the synthesis and study of new materials, institutes of similar size and profile regularly use large facilities such as synchrotron light sources, neutron diffraction facilities etc. Within the School, the orientation towards such facilities is very limited and the Reviewers recommend that perhaps some consideration should be given to this.

3.8 There is a threat that young professors with high potential will leave the School due to the difficult economic/funding situation in Ireland. The Reviewers recommend that a strategy should be elaborated to keep them.

3.9. The Reviewers recommend that the School should consider establishing a help room that undergraduates can drop in to discuss problems, staffed over some time periods by faculty/senior undergrads/postgrads or non-teaching postdocs or scientists interested in developing their teaching skills.

3.10 Theoretical Physics (TP) students take two-thirds of their courses over the first two years from the mathematics department, and so inevitably develop a strong relationship with that department early on. The Reviewers felt that an opportunity was being missed by the School of Physics in fostering their relationship with these students. The Reviewers suggest that the solution may not require more teaching but instead, for example, providing them with more challenging problems during their TP-only small-group tutorials.

3.11 The Reviewers suggest that awarding a number of prizes for good demonstrating might be sufficient to improve morale among postgraduate demonstrators who are no longer paid an hourly rate explicitly for their work in the undergraduate laboratories.

3.12 The Reviewers recommend that a way needs to be found for TP students to undertake a more substantial piece of original work. A single sizeable project is educationally much more valuable than several small projects. The schools of mathematics and physics are planning to discuss co-ordination of the project requirement for TP students so that they can take a single project in either physics *or* mathematics. The Reviewers strongly encourage them to sort this out because it will make this degree more attractive as well as giving these very bright students a better understanding of research work in the school of physics. The staff resource implications of project work are substantial, however, and this should be recognised.

3.13 The Reviewers suggest that it might be worthwhile to consider developing programmes (undergraduate and/or postgraduate) in collaboration with biology or engineering or nanoscience.

3.14 The Reviewers recommend that a more formal workload model, designed by the school, might make the total workload across teaching, research and administration, and its equitable distribution, clearer to staff.

3.15 The Reviewers note that the School is using fairly traditional teaching and assessment methods. These align well with the curriculum, but the Reviewers suggest that there is scope to test out some more innovative approaches to enhancing learning, perhaps getting ideas from the Institute of Physics Higher Education group or other Physics Education efforts worldwide.

3.16 A sub-group of the Teaching and Learning Committee, chaired by the Director of Teaching and Learning (Undergraduate), meets with student representatives roughly once

per term to hear their concerns. This meeting is somewhat informal at present. The Reviewers believe that this meeting does need to be formally minuted in order to make sure that the actions agreed do happen. This would also make clear to students that the school takes their concerns very seriously. Students would be able to see what issues have been raised by previous cohorts and whether an effective solution to any problems has been found.

3.17 The Reviewers recommend that the School should consider having an orientation/ annual meeting for graduate students that tells them about all the opportunities available to them in TCD and other institutions and encouraging them to take them up to prepare themselves for their future careers.

3.18 The Reviewers believe that the TP committee needs to be set up again (currently there is a 'working group') in order to review the TP curriculum and decide what modifications are needed to update this important and prestigious degree, starting with the project requirement.

3.19 The Reviewers note that in terms of outreach to younger students, many departments elsewhere are ramping up outreach activities and they suggest that TCD consider enhancing a few activities to attract students (including female students) to physics. They recommend that perhaps a small number of top secondary students (< 5) could do a larger summer project (≈ 6 weeks) to attract them not only to science but also to physics. The School could also consider a monthly fun lecture aimed at primary students (Spring) and secondary students (Autumn) to nurture interest in physics. Strategic alliances with secondary schools with a good physics curriculum and a diverse group of students could be considered. Perhaps more pictures of female students and scientists could be added to the web page to send the message that they are welcome.

3.20 The Reviewers recommend that the School and College should discuss how resources are allocated based on the number of equivalent teaching faculty in Physics. World-class institutes such as CRANN are set up separately from the schools for a good reason, and have prospered as a result. However, many scientists at institutes have significant responsibilities in research and cannot therefore do as much teaching. This should be taken into account in estimating student to faculty ratios.

3.21 The Reviewers note that one worrying issue in the SNIAM building was the ingress of water through the external wall into research laboratories containing valuable equipment and they recommend that this be addressed rather urgently by the Building services.

3.22 The Reviewers suggest that there is room for some development and reform of the role of Director of Research. The School would also benefit by having a Research Officer to assist academic staff in the preparation of research proposals and in the management of, and reporting on, research projects.

4. PROVOST'S RECOMMENDATIONS TO COUNCIL

In light of the Review Report and the responses from the School of Physics and the Faculty Dean, it is recommended that:

1. The School of Physics working closely with the Dean of the Faculty of Engineering, Mathematics & Science, and other relevant Academic Officers, should consider the detailed recommendations of the Review Report and draw up an implementation plan[2] for Council approval.

2. The University Council should have oversight of the academic workload models and ensure implementation across College.

3. The Trinity education strategy document by the Senior Lecturer should take a more active role in teaching innovation and curriculum development in the School of Physics.

[2] See Procedures and Protocol for Quality Review of Schools 2011/12 at *http://www.tcd.ie/vpcao/quality/assets/pdf/Procedures_and_Protocol_for_Quality_Reviews_of_Schools_2011_12.pdf*

5. REVIEWERS' REPORT

Introduction

The External Review Team, consisting of Prof. Christine Davies (University of Glasgow), Prof. Margaret Murnane (University of Colorado at Boulder) and Prof. László Forró (Ecole Polytechnique Fédérale de Lausanne) reviewed the School of Physics at Trinity College Dublin on March 20 and 21, 2012. During the visit, the team met with leaders from the College and School, including the Vice-Provost/Chief Academic Officer Prof. Linda Hogan, Dean of the Faculty of Engineering, Mathematics and Science Prof. Clive Williams, Head of School Prof. James Lunney and the academic secretary Ms. Patricia Callaghan. The team wishes to thank these individuals for their great help during the review, and also Prof. Bruce Misstear (internal facilitator), Ms. Helen Condon (TCD quality office) and Elspeth Hayes (helped document the review). The team also met with undergraduate and postgraduate students, staff, postdoctoral scientists, faculty, as well as the School Executive in Physics. We also met with the leadership in the Chemistry and Mathematics Departments.

The review team is unanimous in congratulating the School of Physics for remarkable progress since the last review. The School of Physics at Trinity College Dublin has many great attributes that have strengthened greatly since 2003. These include inspired and dedicated leadership, excellent young and old faculty with a good age distribution (27), a growing number of ambitious students at all levels, world class research with an increasing proportion of very high profile research with dramatically increased citations, and an increasing international stature. The School should be recognized for its support of CRANN. Clearly, the ambitious strategic direction that was presented in the last review has paid off, and not surprisingly, not without increased stresses at all levels.

The challenges that the School of Physics is facing are similar to those facing many top departments worldwide. How to preserve research excellence in light of static research funding? How to prioritize internal resources? How to respond to successful young faculty who bring in external funding? How to expand undergraduate teaching excellence, and incorporate the newest ideas in education research to better prepare students for future careers and to attract more interest from students? How to fairly distribute faculty workload (research, teaching, service and outreach) in a world-class department? What is the composition in terms of research area that a world class physics department should have in the 21st century? How to prepare students for a globally competitive workplace, for example by growing new undergraduate and postgraduate degree or interdisciplinary degree programs, or programs that create new 5-year combined engineering-science-business-finance programs? How to attract students from abroad? How to implement effective outreach to encourage more Irish students to pursue science, mathematics or engineering? How to run a growing department (with many more research-active faculty) with constant permanent staff? How to educate staff that more is expected from people at all levels in Colleges?

(a) Research and Scholarly Activity

Assessment of research activity.

The School of Physics at TCD, despite its relatively small size, shows a versatile research activity. Areas such as magnetism, nanoscale physics and technology, nano-biology, photonics, spintronics, astrophysics, econophysics, device physics and soft condensed matter physics are present. Many of these fields are studied both experimentally and theoretically, with a very strong computational physics feature. To this multi-faceted research profile the recently added astrophysical group was a very positive development for the School.

The School benefits from a unique environment in the field of nanosciences from the competences of CRANN and its world-class facilities in nanofabrication and nanocharacterization and its NanoBiology Laboratory. Furthermore, it relies on the Trinity Center for High Performance Computing, on the Optical Analysis Laboratory and the Advanced Microscopy Laboratory.

The strategy of the School to bridge fundamental research and advanced technology in some emerging research fields is very clear and responds to national priorities. Some important research lines are (i) the information and communication technologies, (ii) the engineering of new nanomaterials with controlled functionalities in biology and health (iii) the study of quantum effects in micro and nanostructures, (iv) solar activity and telecommunications. The School of Physics is focusing on basic research activities, but it has a proactive policy to translate results emerging from its research to the marketplace, usually in collaboration with partners. Over the reporting period, this has resulted in the filing of 24 patent applications, and several start-up companies were created.

The very healthy scientific atmosphere is reflected by the bibliometric parameters. Over the reporting period, the scientific output is excellent, namely it consists of about 150 articles/year in international journals generating 2000 citations/year; of over 30 book chapters; 2 books; 682 invited communications in national or international workshops and conferences. Papers were published in high impact factor journals as well, like Nature, Nature Materials, Nature Nanotechnology, Nature Communications, Science, NanoLetters, Physical Review Letters etc. This output is excellent even for schools with a larger faculty. There are a few staff with relatively poor publication records and it would be good to discuss with them how to get their research back on track.

Nanoscale science and interdisciplinary approaches will flourish in the near future which means that the scientific output of the School will continue to stay at a high level, the citations will rise in the next few years. But the most important reason for this optimistic vision is the 11 young and talented people the faculty hired since 2004.

The excellent output of the School is illustrated by few highlights from the rich publication record in the reporting period:

- Ferromagnetism in defect-ridden oxides and related materials
- Donor impurity band exchange in dilute ferromagnetic oxides
- Unexpected magnetism in a dielectric oxide
- Electrically driven phase transition in magnetite nanostructures
- Quantitative time-resolved measurement of membrane protein–ligand interactions using microcantilever array sensors
- An experimental realization of the Weaire–Phelan structure in monodisperse liquid foam
- Two-Dimensional Nanosheets Produced by Liquid Exfoliation of Layered Materials
- Mechanical reinforcement of polymers using carbon nanotubes
- Organic Spintronics: Filtering spins with molecules
- Electrostatic spin crossover effect in polar magnetic molecules
- Propagation of an Earth directed coronal mass ejections in three dimensions

The funding record was very good in the reporting period. It has strongly increased from 2004 to 2008, and it has been decreasing since as a result of the economic background. In order to compensate somewhat for the unfavorable funding situation in Ireland, the School turns more towards European funding agencies. The total income for the 2004-2012 period amounts to 70 M€, which is excellent.

Graduate students. The versatility of the research portfolio and the freshness in addressing modern topics is very attractive for graduate students and post-doctoral researchers. Their high motivation for research was noticeable during the review. The supervision and mentoring of PhD students should be considered – it is generally thought necessary in UK universities to name a second supervisor, not only for a second scientific opinion but also to help when issues arise with the first supervisor.

Research strategic plan

The School has a world-wide reputation as a center of excellence in magnetic, optical, nanomaterials and computational physics. One of the goals is to maintain this leading position. Another plan is to launch interdisciplinary consortia with Schools of Chemistry, Medicine, Pharmacy and Immunology. There is already a limited interaction through individuals working in drug delivery, imaging and toxicity of nanoparticles, but much stronger action is planned primarily through CRANN and its NanoBiology Laboratory. The interdisciplinary strategy is excellent. It matches the tendency present at other leading universities worldwide.

In the synthesis and study of new materials, institutes of similar size and profile regularly use large facilities such as synchrotron light sources, neutron diffraction facilities etc. Within the School, the orientation towards such facilities is very limited and perhaps some consideration should be given to this.

In maintaining the high level of research the School foresees to keep and even increase the number of active research students. They plan to recruit foreign students through international collaborations. The attractiveness of the School for students (graduate and

post-graduate) relies on offering new modules and a modern multi-disciplinary research environment.

The person of the highest international visibility is Prof. Michael Coey, having an exceptional publication record and a long list of honors and awards. He has the most prestigious chair in Ireland, that of Erasmus Smith Professor of Natural and Experimental Physics. With his forthcoming retirement the School should look for a person with equivalent reputation for this chair.

There is a threat that young professors with high potential will leave the School due to the difficult economic/funding situation in Ireland. A strategy should be elaborated to keep them.

(b) Teaching and Learning

The School of Physics offers the premier undergraduate degree programmes in physics in Ireland. The courses are accredited by the Institute of Physics. There is no taught master's programme but postgraduate modules are given for PhD students. The members of the school are strongly committed to their teaching mission and the students that we met were clearly bright, articulate and engaged.

(i) Inputs

Content/level of the programmes and number of students. The content and level of the four-year Bachelor's programmes offered is comparable to that of other Schools of international standing in physics.

The physics and physics and astrophysics degree students enter through the general Science intake and take physics courses for one third of their time in the first two years. There are also two direct entry courses: Nanoscience, Physics and Chemistry of Advanced materials (NPCAM) and Theoretical Physics (TP). The Science entry students are not required to have taken physics in their final school exams and this does mean that the first year course must cater for students with a rather weak background in physics. The school has introduced small group tutorials for first-year students and this is a good way to bring weaker students up to speed, although intensive of staff time. It was not clear to us that this was working as well as it could, although the mismatch between school and university teaching methods always tends to cause first year students some anxiety. The school should consider establishing a help room that undergraduates can drop in to discuss problems, staffed over some time periods by faculty/senior undergrads/postgrads or non-teaching postdocs or scientists interested in developing their teaching skills.

The NPCAM and TP students take a very similar first year physics course, although the NPCAM students have some additional specific non-examinable lectures to introduce them to the kind of material they will be specializing in later on. This has staff resource implications but it seems to be a good way to foster an esprit de corps among these students. Although the TP students form a significantly larger cohort there is not currently any specific provision made for these students in the first two years. They typically come in

with a stronger entry points score than other physics students and reported that they found the first year physics course rather unchallenging. They are also strong in mathematics, of course, which often causes problems for physics students. The TP students take the other two-thirds of their courses over the first two years from the mathematics department, and so inevitably develop a strong relationship with that department early on. We felt that an opportunity was being missed by the school of physics in fostering their relationship with these students. The solution may not require more teaching but instead, for example, providing them with more challenging problems during their TP-only small-group tutorials.

We toured the undergraduate laboratories and were impressed with the general layout and with the equipment. There were some complaints about the helpfulness of postgraduate demonstrators from students and, although this is a common problem often arising from unrealistic expectations on the part of students, it does seem that postgraduate demonstrators are not being adequately trained for their teaching functions in the school. This is damaging both for the undergraduate experience but also for the postgraduate students themselves, some of whom would relish the opportunity to develop their teaching skills. Indeed it seemed to us that, with adequate training, some postgraduate students (or postdoctoral researchers) could give tutorials instead of demonstrating in laboratories and this might alleviate the problem with staff resources for tutorial work. Another issue that arose in conjunction with first year laboratories was the inevitable lack of synchronization between lectures and laboratories when experiments are done as part of a 'rotation'. This made students feel unsure of their understanding of the physics behind some of the experiments. The problem would again be alleviated by improved training of the postgraduate demonstrators.

In the past postgraduate demonstrators were paid an extra hourly rate explicitly for their work in the undergraduate laboratories. This has become financially untenable and the school has decided simply to require this work as part of receiving the PhD stipend. Inevitably this has caused bad feeling in the transition period and the school does not seem to have made enough effort to smooth things over. This, coupled with the lack of training above, has given the rise to the perception that the school does not value laboratory demonstration work. A simple thing, such as awarding a number of prizes for good demonstrating, might be sufficient to improve morale among postgraduate demonstrators (since it seems unlikely that the payments can be reinstated).

The third and fourth years of the physics course cover more advanced topics. Here there is somewhat less choice available to the students than there would typically be in a larger department. A substantial (300-360 hours) project is offered to most students in their fourth year, however, and this is very much appreciated by them. Some students are even able to go abroad to carry out their project work. Others use the world-class research facilities available in the school or in CRANN. Some very impressive work is done and this was commented on by the external examiners and by the Institute of Physics accreditation visit. The only adverse comment that we heard from students on the projects is that they would prefer the oral examination on it to be much sooner after the project report is handed in early in January. Currently the project is not examined until Easter and students find this distracting, reasonably enough, in their preparations for their finals.

The TP students do not undertake a substantial project in physics. A small (50 hours) project is compulsory in physics and they are able, as an option, to take a 10 credit project or 5 credit research assignment in mathematics. However, given the importance of project work, especially for students who want to go on to further research, it seems clear that a way needs to be found for TP students to undertake a more substantial piece of original work. A single sizeable project is educationally much more valuable than several small projects. The schools of mathematics and physics are planning to discuss co-ordination of the project requirement for TP students so that they can take a single project in either physics *or* mathematics. We strongly encourage them to sort this out because it will make this degree more attractive as well as giving these very bright students a better understanding of research work in the school of physics. The staff resource implications of project work are substantial, however, and this should be recognised.

Student numbers in physics are certainly holding steady and even increasing. This is very much to be welcomed by the School and any resource implications of this increase need to be overcome. Currently the school has nearly 300 FTEs, of which nearly 200 are undergraduate and 100 postgraduate. The School graduates 50-60 students per year across its four degrees and the school is expecting that this will rise to ~70 as increased numbers further down work their way up. Physics departments across the UK are experiencing a rise in student numbers and this can become quite marked in courses that have a general science entry (similar to that at TCD) when students switch between sciences after entry. So the rise in numbers in physics at TCD could continue further. In the UK this has caused a squeeze on laboratory space and has meant that laboratories have to be run more often. There seems scope to do this also at TCD. The resource implications of an increased number of students needing projects are significant. One suggestion for ameliorating this that has been used in Glasgow is to allow postdoctoral researchers to supervise projects, as their teaching contribution to the school. This can be beneficial also to the postdoctoral researchers in giving them supervision experience.

It might be worthwhile to consider developing programmes (undergraduate and/or postgraduate) in collaboration with biology or engineering or nanoscience. The increased options available now in astrophysics are very popular with students and it is possible that other more interdisciplinary options could also be attractive. These are the norm in many institutions worldwide, and would have many benefits. Biophysics or biomedical engineering might attract more female students, along with courses that expose students to business/finance. Such a program is very popular at Berkeley now.
Of course such developments have resource implications that may not be affordable in the current climate.

Distribution of teaching across staff members. We were given a table of teaching assignments in which the typical number of contact hours including lectures, laboratories, and tutorials is approximately 100 per staff member. The load is reasonably even, although the split between lectures and tutorials/labs varies. Members of the school feel that the distribution is equitable and we had no complaints of people 'not pulling their weight'. The teaching load seems reasonable when compared to UK universities – the typical number of lectures, for example, is similar to that in Glasgow. A more formal workload model, designed

by the school, might make the total workload across teaching, research and administration, and its equitable distribution, clearer to staff.

Constructive alignment of curriculum, teaching methods and assessment methods. The school is using fairly traditional teaching and assessment methods. These align well with the curriculum, but there does seem scope to test out some more innovative approaches to enhancing learning, perhaps getting ideas from the Institute of Physics Higher Education group or other Physics Education efforts worldwide. This could make the physics courses more attractive in the international marketplace.

Adequacy of staff-student liaison in the School in relation to teaching and learning. The relationship between staff and students in the school is good. One UG and one PG student sit on the School executive committee. This seems to work well although clearly on occasion there will be matters that cannot be discussed with students present. A sub-group of the Teaching and Learning Committee, chaired by the Director of Teaching and Learning (Undergraduate), meets with student representatives roughly once per term to hear their concerns. This meeting is somewhat informal at present. We believe that this meeting does need to be formally minuted in order to make sure that the actions agreed do happen. This would also make clear to students that the school takes their concerns very seriously. Students would be able to see what issues have been raised by previous cohorts and whether an effective solution to any problems has been found.

Supervision and support of students on taught postgraduate programmes. There is no taught Masters programme in the department but modules are taught to PhD students, and they can also access modules in other departments, and even in other institutions. They are required to take modules to a minimum value of 15 credits during the first eighteen months of their PhD. The students seemed generally happy with what was available. They reported a few teething problems with finding out what was available in other schools and matching the requirements of those schools to the requirements of physics.

The School should consider having an orientation/ annual meeting for graduate students that tells them about all the opportunities available to them in TCD and other institutions and encouraging them to take them up to prepare themselves for their future careers. It is important for graduate students to be proactive in developing research, teaching, communication and writing skills.

Arrangements for curriculum review and revision. This is carried out by the Teaching and Learning Committee and there are specific cross-school committees for the NPCAM and TP degrees. The NPCAM curriculum is currently undergoing significant changes following its relaunch in 2010. We believe that the TP committee needs to be set up again (currently there is a 'working group') in order to review the TP curriculum and decide what modifications are needed to update this important and prestigious degree, starting with the project requirement.

Methods used to evaluate teaching and learning in the school. The school uses its own online evaluation of its modules and the results of this were made available to us. This

method seems to be working well and the evaluations were generally very positive. They are also reviewed by the DTLUG who discusses them with individual staff if necessary.

Professional standing. The physics degrees were accredited by the Institute of Physics in 2011 for the full five year period possible.

Opportunities for study abroad. Some students are able to study abroad for their fourth year project, under schemes such as the Erasmus programme. The language barrier is less of a problem for project work than taught programmes. It seems clear, however, that fewer Irish students go abroad than would be needed to 'balance' the requests by incoming Erasmus students.

Funding available to students on postgraduate taught programmes. Not applicable.

Diversity of the student body. An important indicator for schools of physics to track is the percentage of female students in their classes and their success rates and retention rates. We were given the numbers for the final year classes, broken down by degree. The percentage of female students has large fluctuations from year to year because numbers are inevitably small, but the percentages look reasonably healthy compared to UK averages, at about 20%. More analysis of retention rates for male and female students would be useful to check that the degree programmes are sufficiently 'friendly' to female students. Adding some attractive pictures to the School web pages might help to make the school look more welcoming.

(ii) Outcomes

Student exam results and completion rates. These are commented on both by the external examiners and by the Institute of Physics accreditation visit. They seem satisfactory. The external examiners are complimentary about the examination process and believe that the grades awarded reflect the student quality.

Progression paths of students following graduation. A high proportion of the physics students go on to further study, such as PhD programmes, particularly from NPCAM and TP. This is typical of students from a high quality undergraduate programme in physics.

(c) Engagement with Society and Service to College

The review team believes that the faculty is involved in effective outreach and service activities at a very robust level. The faculty of the School of Physics serve the College and the broader science community in many ways, through committee service on safety and alumni outreach committees, as well as service on editorial boards, reviewing, external evaluators on grant and Ph.D. review committees. Highlights of service and engagement with society include the TCD Science Gallery, which grew out of the CRANN center, with support from the department, which is a great, internationally recognized, success. The Science Gallery attracts hundreds of thousands of the public and students at all levels to themed hands-on exhibits, and is a national asset. Other highlights include the named

lectures given by the faculty, the Schrodinger lecture series, the website for secondary schools, the open days of demonstrations and undergraduate laboratory tours, outward visits and the inward visits of secondary students for 1 week to TCD. This Transition Year curriculum has an impressive number of participating secondary students, of up to 300. Up to 60% of students engaged in the latter activities return to TCD to study science.

The School is also very active in applied strategic research in selected areas of technology (PATs), there are 6 spin-off companies either formed or in the process of being formed, and more than half of the School faculty is involved with CRANN, that has many associated industries. In addition, faculty from the school are helping to guide public policy in Ireland (e.g. in energy and science policy).

It is worth noting that in terms of outreach to younger students, many departments elsewhere are ramping up outreach activities. The review team notes that TCD could also consider enhancing a few activities to attract students (including female students) to physics. Some of the following approaches have proven effective elsewhere, and could be explored to see which is effective. Perhaps a small number of top secondary students (< 5) could do a larger summer project (≈ 6 weeks) to attract them not only to science but also to physics. The School could also consider a monthly fun lecture aimed at primary students (Spring) and secondary students (Fall) to nurture interest in physics. Strategic alliances with secondary schools with a good physics curriculum and a diverse group of students could be considered. Perhaps more pictures of female students and scientists could be added to the web page to send the message that they are welcome.

(d) Resources

Academic Staff. There are 27 academic staff in the school, which means that the school is not a large one. On the other hand, its size is a reasonable reflection of the current number of students they have, compared to UK norms. The school is to be congratulated on the international profile it has been able to achieve with this staff complement. The age profile looks healthy with a good number (11) of staff below 45. A few retirements are coming up and it is to be hoped that replacements can be made. This is particularly true of the Erasmus Smith chair for which it is important that a suitably high profile individual is found.

The School and College should discuss how resources are allocated based on the number of equivalent teaching faculty in physics. World-class institutes such as CRANN are set up separately from the schools for a good reason, and have prospered as a result. However, many scientists at institutes have significant responsibilities in research and cannot therefore do as much teaching. This should be taken into account in estimating student to faculty ratios.

There are now (with a recent hire) 2.5 female staff in the school. At 10% this is not very impressive, again comparing to the average of UK or US physics departments, and it would be good if improvements to the gender balance could be made. We strongly recommend that the school engage with the Institute of Physics Juno programme. This programme is specifically designed for physics departments to encourage them to develop and embed good practice in terms of student and staff experience. The school of physics at TCD already

has a lot of good practice in place and getting the recognition for this under the Juno programme (especially since the take-up has been rather poor in Ireland compared to the UK) would encourage more female students and staff to apply to TCD.

Staff development does not seem quite as extensively embedded as in some UK institutions, although this is obviously a college-wide issue and we understand that the college is reviewing the situation. Probationary staff have the opportunity to attend courses in aspects of university teaching but we gained the impression that this was not very popular. Some courses of this kind can be very useful and the importance of reflecting on teaching performance, with a view to improvement, does need to be brought to the attention of young staff. It would be good if there were more encouragement in the school of physics for staff to attend at least some of these courses. It is also normal for a probationary staff to submit a fairly formal annual report to the head of school and for this to be compared to development objectives set for the year, possibly with the help of a mentor. We understand that mentors are in place for new staff but no formal annual reports.

Performance and Development Review of academic staff is a contentious issue and one that TCD will have to take its own view on. One issue is of course the administrative burden placed on staff, but it can be useful for staff to review their progress yearly and it can be important for the head of school to get a picture of what staff have done for an equitable division of duties in future. It is possible that a more developed workload model/workload report could address this adequately.

Note added since the review: we now understand that TCD has put in place mentoring and performance development and review schemes. It will be up to a future review to assess the impact of these.

Administrative staff. There are 7 administrative staff. This might be considered quite a high number but it includes staff dedicated to finance office functions that might be performed elsewhere in other settings. These staff look after the considerable load of managing the finances on the research grants held by staff in physics.

Service support staff. There are 15 technical staff covering both the school of physics, both teaching and research, and CRANN. Some salaries for these staff are recovered on grants. Given the amount of technical equipment this seems a reasonable complement.
The current chief technician is about to retire and the technical staff are anxious that this important position in the liaison between academic and technical staff continue to exist.

Physical infrastructure. We reviewed the laboratory space for both teaching and research. The teaching laboratories were attractive and well set up. The space will come under pressure with increased student numbers but we believe that this can be managed. The research laboratories were very impressive, especially in CRANN, and provide excellent facilities for staff and students. One worrying issue in the SNIAM building was the ingress of water through the external wall into research laboratories containing valuable equipment. This seems to us to be something that needs to be addressed rather urgently by the Building services.

The school has plans to create a better social space in the Fitzgerald building with the dual purpose of providing for staff and students during the day, but also for receptions in conjunction with public lectures in the large lecture theatre. This seems a very good idea to us, since we received several comments that it was difficult for staff and students to mingle over coffee because there simply was not sufficient space in the current tea room.

(e) Organisational Structures and Planning

The department has excellent and effective leadership from the Head of School, Prof. James Lunney, and the School Executive. This team has successfully advanced the department to achieve its goals since the last review, with impressive success in terms of research and supporting the growth of CRANN, while at the same time growing strategic new programs (for example in astrophysics). Very good organizational and planning practices are in place, in terms of financial management, good committee structures, representation of students on School level committees, and attention to the important questions and challenges regarding the future of the department. The review team notes that none of our recommendations were surprising to the Head of School, who is already planning how to deal with many of them. There is room for some development and reform of the role of Director of Research. The School would also benefit by having a Research Officer to assist academic staff in the preparation of research proposals and in the management of, and reporting on, research projects.

This review will be a good opportunity for the School to meet to decide how best to implement ideas that resonate with the department vision, and for TCD and the School to discuss what resources are needed to implement them (many are in process already and not all recommendations require new resources).

(f) Overall view and recommendations

The self-assessment by the department was well thought out and the departmental plan look sensible.

We collect here our **major recommendations** (minor recommendations are made throughout the text).

MAJOR RECOMMENDATIONS

1. To attract more female students and faculty into physics, the school should engage with the Institute of Physics Juno award programme. This has been very successful in the UK in establishing best practices around education and hiring. Attracting more female students and faculty should be a priority given worldwide trends in college education.

2. Although the quality of the undergraduate programme is excellent, there needs to be continuous improvement to attract the best students, and particularly to attract international students. A key degree with a lot of potential that is not being adequately fostered by the school at present is the theoretical physics degree. We recommend that a

joint committee with mathematics is set up to revisit the curriculum and the provision for students in this degree.

3. A more proactive approach to teaching innovation and curriculum development is needed from the Teaching and Learning Committee. We also believe that staff-student liaison with respect to teaching and learning needs to be improved.

4. The training and mentoring of postgraduate students should be improved, for example by the routine allocation of a second supervisor. This person could provide more general advice/encouragement for students to develop transferable skills. The training of postgraduate students (and postdoctoral researchers) in teaching techniques is very important both for their career development and for the undergraduate students in their care. This needs to be taken more seriously by the school, since the standards for effective teaching required to compete internationally are rising. More creative use of postgraduate students and postdoctoral researchers in teaching by allowing them to choose a contribution, for example in tutorials or project work instead of laboratory demonstrating, could help to improve their motivation.

5. To maintain scientific leadership, the College and School should work together to hire a world-class faculty member when Prof. Michael Coey retires. There may also be an increasing need to retain other strong faculty, as is the case with all world-class departments.

6. It would be worthwhile to consider implementing a performance and development review system, to encourage all faculty to contribute and to encourage innovation at all levels (teaching, research, service and outreach). Most faculty can excel at only two of these activities simultaneously, and the distribution may change over time. However, metrics that encourage all faculty to ask how they can contribute to improving the School and College would be good for everyone.

6. SCHOOL'S RESPONSE TO THE REVIEW REPORT FOR PHYSICS

The School of Physics was very pleased to see the very favourable report made by the external review team who carried out a review of all aspects of the School in March 2012. We are also pleased to note their opinion that the School has made a lot of progress since the last School review in 2003. Looking ahead, they point to eleven major challenges and questions facing the School, as follows:

1. *How to preserve research excellence in light of static research funding?*
2. *How to prioritize internal resources?*
3. *How to respond to successful young faculty who bring in external funding?*
4. *How to develop undergraduate teaching excellence, and incorporate the newest ideas in education research to better prepare students for future careers and to attract more interest from potential students?*
5. *How to fairly distribute faculty workload (research, teaching, service and outreach) in a world-class department?*
6. *What is the composition in terms of research area that a world class physics department should have in the 21st century?*
7. *How to prepare students for a globally competitive workplace, for example by growing new undergraduate and postgraduate degree or interdisciplinary degree programs, or programs that create new 5-year combined engineering-science-business-finance programs?*
8. *How to attract students from abroad?*
9. *How to implement effective outreach to encourage more Irish students to pursue science, mathematics or engineering?*
10. *How to run a growing department (with many more research-active faculty) with constant permanent staff?*
11. *How to convey the message that even more effort and commitment is expected from people at all levels in College?*

Consideration of these challenges will help the School of Physics to plot the strategic development of the School over the next decade and beyond.

This report considers the School under several different headings and makes a number of recommendations, both major and minor. The response of the School to these is as follows:

(a) Research and Scholarly Activity

We are delighted with the reviewers' overall comments on the international standing of the School in terms of its research portfolio and scientific output. While the reviewers make no specific recommendations with regard to research, they do point to a number of challenges facing the School in this area, and the School acknowledges its awareness of possible problems. In particular, the reviewers refer to the consequences of static, or declining, research funding and the difficulty that the College has at present in retaining successful

young academics who bring in external funding. If these staff cannot be promoted at an appropriate pace, they will surely consider continuing their careers elsewhere.
Currently the School of Physics is the major academic partner in CRANN. The School will continue to make academic and other appointments in support of the CRANN mission while at the same time maintaining an appropriate degree of disciplinary balance within the School.

(b) Teaching and Learning - Undergraduate

The reviewers make several recommendations with regard to Teaching and Learning (Undergraduate).

Although the quality of the undergraduate programme is excellent, there needs to be continuous improvement to attract the best students, and particularly to attract international students. A key degree with a lot of potential that is not being adequately fostered by the school at present is the theoretical physics degree. We recommend that a joint committee with mathematics is set up to revisit the curriculum and the provision for students in this degree. (Recommendation 2)

In July 2010 it was agreed in principle that the Theoretical Physics (TP) Course Committee should be reinstated and chaired, in the first instance, by the Dean of the Faculty of Engineering, Mathematics and Science. There are informal meetings of key staff from the Schools of Physics and Mathematics to deal with the ongoing management of the course, though the proposed Course Committee has not been established. The School of Physics welcomes the reviewers' advice to re-establish the Course Committee to ensure that this high profile course is managed and developed in the best possible way.

Also in relation to the TP cohort, the reviewers commented that

"…The TP students take the other two-thirds of their courses over the first two years from the Mathematics department, and so inevitably develop a strong relationship with that School early on. We felt that an opportunity was being missed by the School of Physics in fostering their relationship with these students. The solution may not require more teaching but instead, for example, providing them with more challenging problems during their TP-only small-group tutorials."

The School will consider how to improve its relationship with TP students in their Freshman years, perhaps by providing more TP-specific events. It will also continue to provide TP-only small-group tutorials and will investigate ways of making these tutorials more challenging for this talented group of students. The issue of Senior Sophister TP students not having to undertake a major project (as is the case for all other Physics programmes), will be considered by the Theoretical Physics Course Committee.

The review highlighted a number of issues in relation to the Freshman labs, namely the lack of preparedness of the demonstrators (addressed below) and the mismatch between the topics covered in the labs compared with those in the classroom. In relation to the mismatch, the School is considering trialling a system used in the School of Biochemistry and

Immunology in which students watch a video where a demonstrator describes the experiment to be undertaken and provides a series of multiple-choice questions to test the student's knowledge of the background theory. If the trial proves successful, the experiments in the teaching laboratories could be videotaped on a rolling basis, providing the students with a knowledge-base on each topic before they enter the lab, thus improving their learning experience associated with this important part of their course. We will ensure that an appropriate number of the videos are presented by female demonstrators.

The reviewers praised the good relationship between staff and students in the School but asked that staff-student meetings *"be formally minuted in order to make sure that the actions agreed do happen. This would also make clear to students that the school takes their concerns very seriously. Students would be able to see what issues have been raised by previous cohorts and whether an effective solution to any problems has been found."*

It was decided some time ago within the School not to take formal minutes of staff-student meetings to allay any fears that students might have in raising confidential issues. An aide memoire of key items that were discussed at each meeting is made, and progress on these items is reported at the next staff-student meeting. In this way, feedback is given to students on each of the topics raised at the last meeting. We can investigate if students would prefer a more formal system in future.

(b) Teaching and Learning - Postgraduate

The Reviewers made several recommendations with regard to Teaching and Learning (Postgraduate).

The Reviewers' commented that *"The school should consider having an orientation/annual meeting for graduate students that tells them about all the opportunities available to them in TCD and other institutions and encouraging them to take them up to prepare themselves for their future careers. It is important for graduate students to be proactive in developing research, teaching and communication and writing skills."*

The School provides an induction programme for all new postgraduate students that introduces them to Trinity College Dublin and to all requirements of the postgraduate degree. Furthermore, the recently created Innovation Academy can facilitate the development of some of the generic skills mentioned by the reviewers. All 15 postgraduate students in School of Physics funded under PRTLI 5 are obliged to attend at least one Innovation Academy module following their confirmation on the PhD register (after 18 months). The School will survey the students to assess the effectiveness of these modules and determine if they should become an integral part of training for all of the School's postgraduate students.

The training and mentoring of postgraduate students should be improved, for example by the routine allocation of a second supervisor. This person could provide more general advice/encouragement for students to develop transferable skills. The training of postgraduate students (and postdoctoral researchers) in teaching techniques is very

important both for their career development and for the undergraduate students in their care. This needs to be taken more seriously by the school, since the standards for effective teaching required to compete internationally are rising. More creative use of postgraduate students and postdoctoral researchers in teaching by allowing them to choose a contribution, for example in tutorials or project work instead of laboratory demonstrating, could help to improve their motivation. (Recommendation 4)

Regarding the appointment of a second supervisor for PhD students, we already do this where the primary supervisor is in the early years of their career, where the research is done in collaboration with another research group, and when the Director of Teaching and Learning (Postgraduate) considers it appropriate. We are not convinced that routinely appointing a second supervisor is of benefit to the student. The research students and their supervisors are required to submit an annual report to the Director, who will deal with any issues raised. Finally, it is made clear to students that the Director is always available to assist with the resolution of problems connected with their research and supervision. Concerns regarding the effectiveness of postgraduate demonstrators in the teaching laboratories have arisen in recent years. A demonstrator training programme was developed, but was not made mandatory. In line with practice in other Schools, we will develop a mandatory postgraduate module on teaching skills that will provide postgraduate students with proper preparation for laboratory-based teaching.

(c) Engagement with Society and Service to College

Considering how the School of Physics engages with society and serves the College the reviewers make the following comment:

"It is worth noting that in terms of outreach to younger students, many departments elsewhere are ramping up outreach activities. The review team notes that TCD could also consider enhancing a few activities to attract students (including female students) to physics. Some of the following approaches have proven effective elsewhere, and could be explored to see which is effective. Perhaps a small number of top secondary students (<5) could do a larger summer project (≈ 6 weeks) to attract them not only to science but also to physics. The School could also consider a monthly fun lecture aimed at primary students (Spring) and secondary students (Fall) to nurture interest in physics. Strategic alliances with secondary schools with a good physics curriculum and a diverse group of students could be considered. Perhaps more pictures of female students and scientists could be added to the web page to send the message that they are welcome."

The Reviewers make a number of helpful suggestions regarding outreach, pointing out that many departments elsewhere are ramping up outreach activities. The main issue regarding expanding outreach activities is the academic workload. It is expected that the person appointed to the new position of global officer as part of College's internationalization policy will assist in expanding and sustaining the School's outreach activities.

(d) Resources

The report comments that with 27 academic staff, the size of the School is about right for the number of students it has. The report refers to the extra workload for academic staff

arising from their role in CRANN and makes clear that these extra duties need to be considered in assessing individual workloads and the overall staffing complement of the School.

The reviewers suggested having a more formal workload model that *"might make the total workload across teaching, research and administration, and its equitable distribution, clearer to staff"*.

It would be worthwhile to consider implementing a performance and development review system, to encourage all faculty to contribute and to encourage innovation at all levels (teaching, research, service and outreach). Most faculty can excel at only two of these activities simultaneously, and the distribution may change over time. However, metrics that encourage all faculty to ask how they can contribute to improving the School and College would be good for everyone. (Recommendation 6)

The School accepts that a performance and development review system for all staff can make an important contribution to the continuous development of the School. In preliminary discussion of the introduction of a workload model for academic staff, we note the recommendation by Head of School that it should be possible to use a common model in each of the three faculties. The School is very happy to embrace the implementation of a workload model.

Regarding the reviewers' request that the School try to improve its gender balance for both staff and students, the School plans to join the Juno programme of the Institute of Physics (http://www.iop.org/policy/diversity/initiatives/juno/). Initially we will join at the level of supporter but with a view to becoming a practitioner in time; this will increase awareness of the importance of this issue among staff and students.

The School of Education in College offers a Master in Education that is specifically targeted at academic staff in universities (M.Ed. Teaching and Learning (Higher Education)). All academic staff in the School have been notified about this programme and encouraged to participate.

The Chief Technical Officer in Physics will retire in Sept 2012. Currently the College is not in a position to appoint a replacement in the academic year commencing Oct 2012. The School is strongly of the view that this position is critical for the proper management of the technical staff, oversight of the provision of teaching and research facilities and liaison with CRANN on technical matter and issues relating to premises.

(e) Organisational Structures and Planning

The school was pleased to note the reviewers' comment that *"Very good organizational and planning practices are in place, in terms of financial management, good committee structures, representation of students on School level committees, and attention to the important questions and challenges regarding the future of the department."*

The reviewers say that "*The School would also benefit by having a Research Officer to assist academic staff in the preparation of research proposals and in the management of, and reporting on, research projects.*"

This is being addressed at a College level and the School look forward to the appointment of a Research Programme Officer, either full-time or shared with a cognate school/CRANN as seems appropriate.

Response to Major Recommendations
While the School's responses to the reviewers' major recommendations are addressed in the text above, we considered it useful to collate the responses to their six major recommendations separately.

1. To attract more female students and faculty into physics, the school should engage with the Institute of Physics Juno award programme. This has been very successful in the UK in establishing best practices around education and hiring. Attracting more female students and faculty should be a priority given worldwide trends in college education.

We will address the issue of attracting more female students by participating in the Institute of Physics Juno award programme. A person to take responsibility for this task will be identified at the next meeting of the School Teaching and Learning Committee, to be held in June 2012.

2. Although the quality of the undergraduate programme is excellent, there needs to be continuous improvement to attract the best students, and particularly to attract international students. A key degree with a lot of potential that is not being adequately fostered by the school at present is the theoretical physics degree. We recommend that a joint committee with mathematics is set up to revisit the curriculum and the provision for students in this degree.

In July 2010 it was agreed in principle that the Theoretical Physics (TP) Course Committee should be reinstated and chaired, in the first instance, by the Dean of the Faculty of Engineering, Mathematics and Science. So far, the Course Committee has not met, though there are informal meetings of key staff from the Schools of Physics and Mathematics to deal with the ongoing management of the course. The School of Physics is fully supportive of the advice to reestablish the Course Committee to ensure that this high profile course in managed and developed in the best possible way.

3. *A more proactive approach to teaching innovation and curriculum development is needed from the Teaching and Learning Committee. We also believe that staff-student liaison with respect to teaching and learning needs to be improved.*

We agree that the Teaching and Learning Committee should take a more active role in teaching innovation and curriculum development. To this end the next meeting will discuss proposals for a restructuring of the teaching of computational physics throughout each of the four-year undergraduate programmes so that students leave with a thorough knowledge of, and competence in using, at least one programming language.

The School is also involved in discussions with the School of Chemistry and CRANN in relation to the development of a taught MSc in Nanoscience, ideally to be offered from September 2013. Initial contact has been made with directors of similar programmes in the UK in order to learn from best practice in the area and to implement the programme in as cost-effective a manner as possible.

4. The training and mentoring of postgraduate students should be improved, for example by the routine allocation of a second supervisor. This person could provide more general advice/encouragement for students to develop transferable skills. The training of postgraduate students (and postdoctoral researchers) in teaching techniques is very important both for their career development and for the undergraduate students in their care. This needs to be taken more seriously by the school, since the standards for effective teaching required to compete internationally are rising. More creative use of postgraduate students and postdoctoral researchers in teaching by allowing them to choose a contribution, for example in tutorials or project work instead of laboratory demonstrating, could help to improve their motivation.

Regarding the appointment of a second supervisor for PhD students, we already do this where the primary supervisor is in the early years of their career, where the research is done in collaboration with another research group, and when the Director of Teaching and Learning (Postgraduate) considers it appropriate. We are not convinced that routinely appointing a second supervisor is of benefit to the student. The research students and their supervisors are required to submit an annual report to the Director, who will deal with any issues raised. Finally, it is made clear to students that the Director is always available to assist with the resolution of problems connected with their research and supervision. Concerns regarding the effectiveness of postgraduate demonstrators in the teaching laboratories have arisen in recent years. A demonstrator training programme was developed, but was not made mandatory. In line with practice in other Schools, we will develop a mandatory postgraduate module on teaching skills that will provide postgraduate students with proper preparation for laboratory-based teaching.

5. To maintain scientific leadership, the College and School should work together to hire a world-class faculty member when Prof. Michael Coey retires. There may also be an increasing need to retain other strong faculty, as is the case with all world-class departments.

The School is eagerly awaiting permission from the College to commence the search for a new Erasmus Smith's Professor of Natural Philosophy (1724). A substantial start-up fund has been amassed and the School is working with Trinity Foundation to increase that fund.

6. It would be worthwhile to consider implementing a performance and development review system, to encourage all faculty to contribute and to encourage innovation at all levels (teaching, research, service and outreach). Most faculty can excel at only two of these activities simultaneously, and the distribution may change over time. However, metrics that encourage all faculty to ask how they can contribute to improving the School and College would be good for everyone.

The School accepts that a performance and development review system for all staff can make an important contribution to the continuous development of the School. Discussions have already commenced at various levels in College regarding the introduction of a workload model for academic staff. We note the recommendation by our Head of School that it should be possible to use a common model in each of the three faculties. The School is very happy to embrace the implementation of a workload model at the earliest opportunity.

Finally, we wish to record our thanks to the external reviewers, the internal facilitator (Bruce Misstear) and to all of the College staff associated with the review for the friendly and efficient way in which it was carried out. It is most helpful to have this kind of input as we take stock of our current position and undertake to plot a route for development in the future.

7. FACULTY DEAN'S RESPONSE TO THE REVIEW REPORT FOR PHYSICS

The Dean welcomes the very favourable Report on the School of Physics which reports that the School has made much progress in the time since the last Review, in maintaining its strengths and addressing and correcting the deficiencies identified at that time.
The Dean also notes the reviewers' comment that the School recognizes there are still some issues for concern and are already working to address these issues. These issues include gender balance in staff and students, supports for weaker students, more challenging courses/modules/projects for stronger students especially in Theoretical Physics, better training and supports for PG demonstrators, work-load models, student staff liaison, mentoring, etc.

The reviewers highlight and the Dean acknowledges, the need to maintain academic disciplinary balance in the School if Physics is to be an undergraduate degree subject. This balance is currently under pressure due to resource and policy decisions, both internal and external to Trinity College, and also CRANN's current focus on only some areas of Physics.