TRINITY COLLEGE DUBLIN

Report to Council on the Review of the School of Mathematics

November 2014

This report presents the outcome of a Quality Review of the School of Mathematics which was undertaken from 24 -26 March 2014 by Professor Chris Hull, Imperial College London, UK; Professor Maxim Kontsevich, Institute of Advanced Scientific Studies (IHES), France and Professor Anne Taormina, Durham University, UK. The internal facilitator was Professor Sylvia Draper, Trinity College Dublin.

The report attached includes (i) the External Reviewers' report received on the 9 June 2014, (ii) the response from the Head of the School of Mathematics received on the 23 July 2014 and (iii) the response from the Dean of the Faculty of Engineering, Mathematics & Science received on the 15 September 2014.

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.

The Review Report and recommendations, along with the responses from the School and the Dean of Engineering, Mathematics & Science were discussed at the Quality Committee on 30 October 2014. The Head of School, Professor Sinéad Ryan, was in attendance. The full discussion on the Review Report and responses is recorded in QC minute QC/14-15/009.

Table of Contents

Review of School of Mathematics

Trinity College Dublin

Reviewers Report

24 - 26 March 2014

1. **Overview**

   The School of Mathematics is a world-class department with a high international profile based on research excellence and strong teaching. It will be further strengthened by forthcoming appointments in theoretical physics, but the difficulties in filling the Erasmus Smith's Chair of Mathematics and the Accenture Professorship of Mathematics are a cause for concern – it is urgent that suitable high quality appointments be made in pure mathematics soon.

   The recent drastic cuts in research funding are a major threat to the School and its research activities. The opportunities for funding from alternative sources are limited, but need to be explored. However, some of these have associated dangers that could have a negative impact on certain aspects of the school, so that caution is needed in following these. The numbers of graduate students and of post-doctoral researchers are both too low for a department of this calibre, and raising funding to increase these should be a priority.

   One of the School's greatest assets is its strong international reputation and high position in global rankings. A number of overseas graduate students that we interviewed said this was a major factor in attracting them to TCD. The prestige of the School is something that Trinity College can and should do much more to exploit and publicise, using it to raise money from philanthropic sources and to attract overseas students. It is important that this strength is defended and protected against the current threats from funding cuts and financial difficulties.

   On the teaching side, a major decision to be made is whether to introduce a new Masters course. This could be an important positive step with many advantages, but would need to be properly resourced. A careful costing is needed to see whether this could be financially viable in the long term.

2. **Research and Scholarly Activity**

   Research Quality and Output

   The School of Mathematics comprises sixteen full time permanent academics, with seven engaged in theoretical physics research and nine in pure mathematics research. It will be further strengthened by forthcoming appointments in theoretical physics. The research is of excellent quality overall and is internationally leading in some areas, particularly in string theory and its interface with pure mathematics, in integrable systems and in lattice QCD. The research output has been steady during the period covered by the review, with some articles having received a substantial number of citations. Papers are usually published in internationally leading scientific journals such as *Inventiones Mathematicae, Mathematische Zeitschrift, Advances in Mathematics, Algebra and Number Theory, Journal of High Energy*

Physics, Physical Review Letters, Classical and Quantum Gravity, Nuclear Physics B.

Postgraduate Research Students

The number of PhD students graduating has increased from 2 or 3 to 6 over the last five years. Three recent graduates went on to postdoctoral positions abroad. For a department of the calibre of the School of Mathematics, the number of graduate students is low, as is the number of postdoctoral researchers. It is very important to attain sufficient numbers of graduate students and postdocs to achieve the 'critical mass' needed for seminars, advanced lectures, reading groups and journal clubs, and to foster a healthy research environment. This would in turn encourage potential supervisors to attract and supervise more PhD students.The lattice QCD group has succeeded in attracting funding to provide the necessary critical mass in that research area, but the situation is far from satisfactory for the rest of the School.

The recent cuts in funding affect support for graduate students, and the School is in danger of seeing the number of studentships falling, with serious consequences for sustainability. For a leading research department, we would expect an average of two PhD students per permanent member of staff. Increasing graduate student numbers should be an important priority. However, it is vital that standards be maintained, and that all students taken on should be of sufficient ability for a good Ph.D. at Trinity – taking on less able students just for the funds they bring can be counterproductive, affecting morale of supervisors and taking up a disproportionate amount of their time, and not helping the reputation of the School.

The creation of prestigious Hamilton scholarships to be offered from 2014 to attract the best graduate students is a commendable initiative, and the panel was pleased to learn that it had the strong support of the Dean of Faculty of Engineering, Mathematics and Science, who recognises the threat to the School's graduate programme caused by the SFI funding cut.

In the absence of Irish funding, any further increase in student numbers would have to come from recruiting students who had their own funding, or from philanthropic funding. There is real scope to recruit overseas students, as there are a number of countries with generous funding to study abroad. This would both improve the research atmosphere and bring funding to the School through fees. A number of current overseas graduate students said the School's strong international reputation and high position in global rankings were major factors in attracting them to TCD. The prestige of the School is a great asset that Trinity College should use much more to attract overseas students. The new officer for globalisation that will join the School from next year could play an important role in this recruitment.

The quality of the current PhD students is good, with a mix of students from the TCD undergraduate programmes and from overseas, most notably from Germany. This particular foreign connection has been facilitated through a foreign member of staff, and is a good first step towards globalisation, a current prominent objective at TCD. The students appear to be satisfied with the working conditions and the level of attention they receive from their supervisors. They consider the staff to be very approachable and the progress report within 18 months of starting their PhD to be useful. Several students feel somewhat isolated and would welcome the

creation of advanced taught modules in theoretical physics and pure mathematics to enrich their academic experience. However, they are conscious of the current funding situation that makes this difficult. We discussed the possibility of joining a virtual inter-universities network modelled on the MAGIC group that runs a wide range of postgraduate-level lecture courses in mathematics, using video conferencing technology, and there was some interest in this from the students. We note that although some taught modules have been made available to postgrads after the 2007 review through the Simulation Science Programme with University College Dublin (UCD), Queens University Belfast (QUB) and National University of Ireland (NUI), there has been little progress in trying to join forces with other universities to provide Masters level courses in pure mathematics and string theory. One reason is the lack of sufficient strength in some of the relevant subjects in other Irish universities, but this could be looked at further, perhaps including universities in Northern Ireland and using video conferencing. We stress that the lack of critical mass in some subjects researched in the School presents a real risk of severe isolation, exacerbated by the lack of other Irish universities covering the same research areas and the recurrent extremely low number of postdoctoral researchers in the School.

The students are satisfied with the computer facilities, the on-line journals and the use of the Mathematics Library, but they were concerned by the poor condition of some books and journals that have been damaged by dampness in the basement library.

Postdoctoral Fellows

There is only one postdoc at present, working in Mathematical General Relativity using PDE methods. This is far too low a number for the quality of the School. Ideally, a world-class department should aim for at least one postdoc per two research-active permanent members of staff, but certainly a couple in the areas of particular strength is a must. The School's reputation should attract high quality postdocs who would stimulate discussions with PhD students and bring expertise complementing that available in the School, contributing to an enhanced research activity in the School. The drastic cut in funding from SFI and other sources has been responsible in large part for the very low number of postdoc researchers, and every effort must be made to seek alternative funding for postdocs.

Research Funding

The recent economic crisis in Ireland is undoubtedly having severe consequences on the funding of research in Ireland. Theoretical physics and pure mathematics in Ireland are under serious threat, following recent dramatic changes in the scientific funding landscape. The current policy of the Science Foundation Ireland is that the core research activities of the School of Mathematics are no longer within its legal remit and so will no longer be funded by new grants. This results in a drastic cut in research funding and leaves the School with extremely limited funding possibilities. Nonetheless, raising research funding is vital for the School.

It is clear that the difficulties to secure research funding, despite a continuous flow of good applications, have a very detrimental effect on the staff morale. The lack of support played a role in the recent loss of staff in computational neuroscience,

and if the situation persists, there is a real threat of a 'brain drain'. Retention of staff could become an increasing issue in the next few years. The difficulty to fill the Erasmus Smith's Chair of Mathematics and the Accenture Professorship of Mathematics may be partially due to the current climate of financial uncertainty.

The School of Mathematics still enjoys limited tail-end funding from Science Foundation Ireland but this will run out by 2015. The Irish Research Council is now the sole national funding agency for the School, and members of the School regularly apply for funding there, but the available resources from the IRC are limited.

The Dean of Research at TCD explained that public research funding is now driven by political concerns, and that the government wants to invest in areas where there is potential industrial backing and which are likely to lead to immediate economic benefits.

When asked whether there was a concerted effort of Irish Universities to approach the Government and highlight the funding issues faced by pure mathematics and theoretical physics in particular, the School representatives told us that most of the other universities did not feel they had a problem, as their research was more on the applied and applicable side, and so was still funded by SFI. If there is to be any hope of changing the policy of the SFI, it is important that there be a vigorous and sustained campaign. There is a strong economic and social case to be made for maintaining centres of excellence in blue-sky fundamental research in science generally, and for mathematics and theoretical physics in particular. For example, it is often fundamental research that inspires young people and attracts them to science. The skills of students highly trained in problem-solving in mathematics and physics are attractive to employers in a wide range of areas, including ones not directly related to the subjects of study. This is particularly relevant to Ireland, with its involvement in high-tech industries. Such a campaign is something that TCD can and should take a lead on, as the leading research university in Ireland. An important step will be to convince the other Irish universities to join the campaign – they need to understand that they are all vulnerable to further cuts.

An important question for the School is whether it should move into the research areas that the SFI now funds. This is presumably what the SFI policy seeks to encourage. First, it is important to safeguard and protect the current excellence and international reputation in theoretical physics and pure mathematics, and current members should not be pressed into working in more applied or applicable directions. However, it is worth considering whether new appointments could be in areas that SFI would fund. The currently envisaged new appointments in theoretical physics and pure mathematics should still be in these areas, so here we are talking about the possibility of a further expansion into new areas. This might make particular sense if it was part of the recruitment needed for a new Master's programme (see the relevant section) and would allow new courses in the new fundable areas. A careful costing would be needed to establish whether the research funding and the increased funding from students fees would sustain such new positions in the long term. It is also important that any such expansion ensure that the high standards of the School are preserved, and that all new appointees have a high academic calibre.

An important potential source for funding is the EU. Since 2007, twelve applications to the European Union have been lodged, and four have been successful. We have

been told that the lack of commitment from the national funding agencies reduces the chances of success considerably, as the EU is reluctant to fund activities that have little support from national agencies.

The College view is that funding must be grounded in the individual's expertise and excellence, and the Dean of Faculty of Engineering, Mathematics and Science was very supportive of the School of Mathematics. However, there is very little opportunity to divert money within the College, and the strategy is to create studentships and support the postdoctoral programme, encouraging staff to look for innovative funding streams and increase the effort to gain philanthropic support.

The TCD Research Strategy promotes and supports a number of multidisciplinary themes. The only theme that involves a significant amount of mathematics is the 'Mathematics of Complexity', which hopes to draw together research across College that involves modelling, simulation and analysis of complex systems. We learned that some members of the School are involved in this through the High Performance Computing strand of their research, and that one mathematics postgraduate student is supported to work on statistical properties of large networks at the CTVR. However, most members of the School work in areas that are difficult to link to this theme. As TCD focuses much of its support for research to these themes, this means that in effect the TCD Research Strategy does not support most of the research of the School of Mathematics. As the School of Mathematics is currently in such dire need of research funding, we recommend that TCD consider whether its future Strategy could offer more support for Mathematics, either by introducing a theme that builds on the international strengths of the School, or by finding alternative ways of diverting funds to support research in Mathematics.

Hamilton Mathematics Institute

The HMI was a showcase for TCD and Ireland in the few years after its creation (in collaboration with the Dublin Institute of Advanced Studies), partly through its international programme of workshops and conferences and partly through its efforts to enhance public understanding of science. However, the recent decline in funding has forced the HMI to put its activities on hold. The panel thinks that this state of affairs is very unfortunate. The HMI is not a priority for fund-raising at TCD, and it seems that currently no funds are being raised for it. The Dean of Research explained that TCD has five Research Institutes that can make applications for strategic core funding and which are priorities for fundraising from private sources. Despite its name, the Hamilton Mathematics Institute (HMI) is regarded by TCD as a Centre, not an Institute. There is scope for it to become a full fledged Institute, but only if it demonstrates that it is inherently sustainable. This requires the identification of new funding streams in cooperation with other TCD Schools. We recommend that TCD make the HMI one of its priorities for fundraising. Furthermore, we would like to encourage the School to actively seek collaborations with external bodies like the Royal Dublin Society, the British Council and the Irish Mathematical Teachers Association to rekindle their outreach activities, while revisiting strategies to attract philanthropic funds to re-start highly visible conference and lecture programmes.

3. **Teaching and Learning**

Undergraduate Teaching

The School of Mathematics attracts undergraduate students of extremely high calibre. They are proud to study at TCD and are offered a challenging and very interesting curriculum, both in mathematics and theoretical physics, with a strong emphasis on research-led teaching. The Theoretical Physics degree, offered in combination with the School of Physics, is quite unique as it requires students to keep strands in experimental and theoretical physics until the junior sophister year. This set-up is not usual in other leading international Schools, but has the benefit of forming physicists with a very strong background across the physics spectrum. We were pleased to hear that the School of Mathematics and the School of Physics now work well together to deliver a high quality course.

The panel notes with satisfaction that the recommendation by the 2007 review team to put the teaching of algebra on a more stable footing, without having to rely on occasional junior lecturers or retired members of staff, has been implemented through the hiring of new permanent staff with expertise in representation theory and algebraic geometry. Unfortunately, some other important areas of pure mathematics, such as topology and number theory, are still under-represented in the undergraduate programme. With the current number and expertise of staff however, broadening the curriculum is difficult. It is important that the Erasmus Smith's Chair of Mathematics and the Accenture Professorship of Mathematics be filled to strengthen pure mathematics teaching.

The teaching is reasonably distributed amongst the staff, and the panel was pleased that the importance of research leave is recognised and sabbaticals are supported. The panel was told that the average load per staff is around one hundred and forty contact hours a year. This number of contact hours is quite high, but not unusual in comparison with other departments of international standing in mathematics and theoretical physics. The strong commitment of the School to service teaching, that was highly commended by the other Schools during the review, contributes to a higher teaching load. We also note that some teaching is covered by retired members of staff, and that the School would face difficulties if these retired scholars decided to disengage. If there were to be any increase in teaching, from an increase in the School's involvement in service teaching, from the introduction of new courses, or from the establishment of a new Masters degree, the panel would recommend that this be done through the hiring of more staff rather than any increase in the teaching load.

There is no uniformity in the amount of tutorials per module, and the decision to provide tutorials (which mostly take the form of problem-solving sessions with the whole class) is left to the module leader. This is somewhat different from what happens in universities in the UK, where problems classes and tutorials are an intrinsic part of the teaching. There is also a strong correlation between the expertise of the staff and the courses taught at sophister level, so that the curriculum in the last two years of undergraduate studies can be significantly affected by staff leaving the School or taking leave. We were assured that this effect is much less pronounced during the first two years of the degrees.

We were told by undergraduate students that concerns with their courses were

channelled through the course representatives to the individual lecturers, but they would welcome regular meetings with all course representatives, the director of undergraduate studies and the relevant lecturers present. They confirmed that their concerns were usually addressed swiftly, and they found the staff very approachable.

Examination results, retention and completion rates

The panel was concerned by the relatively high undergraduate drop-out rates, such as the 25% drop-out rate for students who registered for the Maths degree in 2010/11. The drop-out rate for the Theoretical Physics degree over the same period was around 20%. The high drop-out rate was also raised by the 2007 Review Panel. This suggests there is either an issue with the recruitment process, or with the course. The competitive entrance requirements select students of the highest quality, so they should be sufficiently able for the course. Nevertheless, the student representatives said that many new students found the course much harder than expected, and perceived other courses in Trinity College to be considerably easier, prompting a number of these drop-outs to change to other courses. A key question to address is whether a high proportion of students is misinformed as to how demanding the course is, or whether the course is too demanding, given that even top mathematics students from Irish schools are dropping out. In particular, the jump from the mathematics learned in Irish schools to what is required at TCD may be too great and act as a deterrent to starting students. We recommend that the School look into the causes of this high drop-out rate, and see what can be done to address it.

We note that external examiners in recent years have expressed concerns about the rate of failure in some Junior Sophister modules, but we were assured that the School had acted on the external examiners' suggestions, including (1) all sophister exam papers and solutions are reviewed at a meeting of staff teaching sophister modules to check for consistency and content, (2) at an external's suggestion, the number and format of questions was standardised in most papers.

Changes in School Syllabus

Irish second level schools have recently introduced a new approach to mathematics teaching that places an emphasis on developing problem-solving skills. This, combined with additional CAO points awarded for studying higher-level maths, has led to an increase in students at university with higher-level maths, and to changes in the material they have covered in comparison with previous years. It appears that students will come to TCD having acquired less traditional mathematical skills than previously, particularly in areas such as calculus. We were pleased to see that a meeting with members of the National Curriculum Development agency was held at TCD in 2012 to explore the implications of this for the undergraduate course and that the School has reviewed material taught to all students in the first year to ensure there is a smooth transition to third-level.

In the UK, a direct consequence of changes in the amount of mathematics learned at secondary school has been that students entered university with much less technical knowledge and less exposure to mathematical thinking. To palliate this deficit, new modules were created in many universities, and in the longer term many 3-year degrees in mathematics or physics evolved into 4-year courses, with three years for

a Bachelor's degree, and an extra fourth year for a Master's. These lead to roughly the same final level, but use the extra year to cover material that hitherto had been covered in secondary school.

The implications of second level syllabus changes for the teaching of mathematics at TCD should not be underestimated. Indeed, first year cohorts who have emerged from second level education prior to these changes are already finding the transition to undergraduate courses from mathematics at second level quite sharp, contributing to the retention problems discussed above. It is important for the School to monitor and review the effects of such changes on first year teaching, and be prepared to implement further changes to the Mathematics and Theoretical Physics degrees as needed.

Proposed New Masters Course

There was considerable discussion of the possibility of introducing a taught M.Sc. programme in Mathematics and Theoretical Physics. This had already been part of the strategic plan for 2010-14, but had not proved possible so far due to insufficient resources and obstacles to using some existing advanced undergraduate courses.

Such a Masters course could transform the School and could help resolve a number of issues discussed elsewhere in this report. On the one hand, some existing advanced undergraduate courses could become part of the Masters course, and further advanced courses could be developed and also benefit first year PhD students. On the other hand, new undergraduate courses in the first year could help bridge the gap between school mathematics and university courses and cover the material no longer taught in schools, contributing to increased undergraduate retention. A Masters course could also bring in much-needed funds if sufficient numbers of students could be recruited, especially from overseas. This would require careful marketing of the course, as it would be competing with other Masters courses overseas. It could also be an important asset in recruiting PhD students, as the best MSc students could could be encouraged to stay on for a doctorate. For PhD students who hadn't taken the Masters, the advanced courses would be an important part of their training, and would make the graduate student experience in the School more attractive.

However, running such a course would require a fair amount of extra resources to enable the creation and delivery of new advanced modules, and to cope with the initial stages of the programme, if the current undergraduate course had to run for existing students in parallel with the new Masters teaching. The current teaching load on existing staff is already high and should not be increased, as this would have a detrimental effect on research and on morale.

The recruitment of extra staff would provide an opportunity to consider hiring in areas that are within the SFI remit. This would attract fresh research funding and could lead to the development of courses in areas that are attractive to potential international students for either the undergraduate course or the new Masters. However it is important that, in hiring in new areas, standards be maintained and only academics of high research ability are considered. Such a new course would bring substantial benefit, but would require a serious investment from TCD in the initial stages. Before going ahead, it is essential that there be a market study to

estimate the likely number of Irish and overseas students, as well as a careful costing and business plan to assess the financial viability of the course in the long term.

Masters in High Performance Computing

The review team met the taught postgraduate students registered for the Masters in High Performance Computing. Some had been undergraduates at TCD, and some came from abroad. They were clear about their motivation to apply for the course, and most had made plans for the future. They chose to apply to TCD because of its high ranking in the international league tables, and because the course offered good value for money. They confirmed there were no problems with the admission procedure, and that the course met their expectations. They are looking forward to their project work, and have a good relationship with their supervisors. There is no funding stream for taught masters, so foreign students rely on scholarships from their governments or are self-funded, and occasionally rely on income from teaching for the School of Mathematics or from jobs outside TCD. Some mentioned that they had followed courses online to broaden their knowledge, and the students would be interested in more virtual courses with the possibility to interact with the lecturer via the live video-conference facilities. Such initiatives exist abroad, in particular the MAGIC network in the UK. The students also travel by bus to University College Dublin to follow some postgraduate courses there, and would consider travelling to Belfast too, if interesting courses were organised there.

4. **Engagement with Society and Service to College**

The School has been successful in attracting high-profile mathematicians to deliver occasional public lectures, and the staff engages in outreach activities, in particular those aimed at school children. These activities are relatively modest, as was to be expected given the lack of manpower to drive them. Increased visibility of the School would be beneficial, especially as a mean to raise awareness in preparation for fundraising. Webpages dedicated to engagement in society would contribute to this effort.

There has been some representation of the School on College committees, including the TCD Board. There is scope for more engagement, although the small size of the School is a disadvantage in that respect. The senior members of the department appear to have a good working relationship with the TCD governing body, and with other TCD Schools where Maths is taught or where Maths students are taught. The panel notes that there is a commendable effort from the Head of School to explore interdisciplinary opportunities for the members of the School, and to engage with the strategic theme of 'Mathematics of Complexity' in order to diversify funding.

5. **Resources**

Staff

The School enjoys a very high international academic reputation and the staff continues to produce high quality research. However, the cuts in research funding together with the cuts in salary that were part of the Irish austerity measures are affecting morale and the ability to recruit top people.

The panel was pleased to hear that the School is about to fill two positions in Theoretical Physics, and that the shortlist for these positions is very strong. These positions will secure the Theoretical Physics group's position as a world-class research team.

We are concerned that the Erasmus Smith's Chair of Mathematics and the Accenture Professor of Mathematics position remain vacant, and that there have been problems in filling them. The Accenture Professorship had been offered to an excellent candidate, with substantial effort being made to attract him to TCD, and it was disappointing to hear that although the candidate had accepted the Chair in January 2014, he would be leaving at the end of June. The pure mathematics group is quite strong for its small size, but it urgently needs world-class appointments to fill the two positions. It was encouraging to hear that TCD was adopting a flexible and open-minded approach to filling these positions, including considering the possibility of replacing a senior appointment with two junior ones. Making strong pure mathematics appointments should be a high priority.

The School is at risk of losing its high international academic standing if financial support remains low. Indeed, the School struggles to reach critical mass and appears to have difficulty to reinvent itself in a world where the development of technologies and industrial collaborations are driving the funding. Although some members of the School can hope to align with some of these research agendas, such an alignment is difficult and inappropriate for most staff of the School, as they work in traditional areas of mathematics and theoretical physics. In a mathematics department three times the size of TCD in the UK, the diversification of research areas allows for such fundamental research to be subsidised by funding for more applied areas. At TCD, the subsidies can only come from College. It might be a good time for the School to consider hiring in areas compatible with the remit of the SFI and the interdisciplinary agenda. This would be particularly worth considering if there is to be an expansion of the staff for a new Masters course.

It should be possible for the number of postgraduate students to increase with Hamilton scholarships and the recruitment of overseas students, but an immediate problem is the very low number of postdoctoral staff. It is important for the School to find new sources of funding and to hunt for and encourage young talented researchers to apply for IRC or European postdoctoral fellowships.

We were impressed with the administrative staff, who work hard to ensure a good student experience and proper support to the researchers. They have been affected by the freeze on promotions and unfortunately the SFI funding for one of the three support staff positions will come to an end in September. They are very important for the smooth running of the School, and it is essential that they get the support and recognition they merit.

Physical infrastructure

The School occupies two and a half listed town houses, together with part of a modern interdisciplinary building hosting the lattice QCD staff and the Masters students in High Performance Computing. The town houses offer adequate space at present, but only allow for a small increase in numbers. The panel commends the meeting room for undergraduate students and the friendly coffee room that stimulates interactions among the staff. There are however serious maintenance problems, including a leaking roof that is a potential health hazard as it encourages substantial growth of fungi and mold on ceilings and walls, but could also lead to disaster if rain water runs along the many exposed electrical cables and fittings. One room has such an unpleasant smell from damp and rot that it is unusable. Damp is damaging valuable books and journals in the basement library. Some teaching rooms and computer rooms have big windows but no blinds, and overheat in the summer months. Despite all these shortcomings, the students are able to cope with the physical conditions, and appreciate the possibility to access the building day and night. The leaking roof and damp problems need to be addressed, as they raise serious health and safety issues. They are also a deterrent for potential students or staff members the School may wish to attract.

6. Organisational Structures and Planning

The main committee structure of the School is comparable to that of most departments of mathematics in the UK, but the School should envisage the creation of small committees with specific missions, e.g. a programme review committee that would take a more global view on the maths course content, especially in the light of changes in the secondary school maths curriculum. It would be desirable to ensure that each module can be taught by at least two members of staff, so that there is always a reserve, although this may be difficult given the small size of the department. This would address the problem of modules being discontinued if a member of staff leaves the School or goes on sabbatical, and ensures stability and quality of the programmes offered by the School. The programme review committee should take into account the views of the students, which should be channelled through a structured staff-student committee. The creation of such a committee was strongly supported by the students we interviewed.

The School's strategic research plan was established for the period 2010-2014, and unfortunately it was not possible, in the light of the funding situation, for four of the five objectives to be attained. The central ambition is to foster research at the highest level, which is of course commendable. In the current economical climate, the School should seriously reflect on the areas in which any future permanent appointments should be. The two positions in theoretical physics, the Erasmus Smith's Chair of Mathematics and the Accenture Professorship of Mathematics should be filled as planned, but as discussed in other sections here, there could be other appointments in new areas if they could be supported by extra funds from student fees, or research funding from SFI or elsewhere. These might be in areas actively supported by the SFI, or aligned with the College Strategic Plan, or areas offering diversified skills and hence attractive to students, in particular from overseas. It would offer the possibility of diversifying the skills transmitted to students, and so could attract more of them, in particular from overseas.

The School has made good progress in improving the quality of their Moderatorship programmes, and in liaising constructively with the other Schools where mathematics modules are taught. Planning should consider to what extent it is viable for the School to broaden their role as the primary provider of mathematics modules in the College, in the short term.

Globalisation

Global Relations have now become a major part of the TCD strategy and the School of Mathematics will have a Global Officer from next year, in a position that will continue if the post proves to pay for itself. In a time of financial difficulties, global relations offer an important opportunity for boosting funds. One route is by promoting the School internationally, through alumni events and international contacts to raise the profile for fundraising. Another is by recruiting undergraduate and graduate students from overseas, with non-EU students in particular paying substantial fees. Modest targets are suggested by the School for the recruitment of non-EU students. This builds on existing initiatives, most significantly a promising link with Tbilisi founded on personal contacts.

Recruiting foreign students is one of the few opportunities available for raising funds. Experience in the UK and elsewhere suggests that substantial numbers can be recruited, and this has transformed the fortunes of some UK mathematics departments. The School of Mathematics has so far adopted a cautious approach, concerned that a large influx of students could lead to changes in the ethos and character of the courses, with the danger that some of what is valuable about the courses could be lost. This is a valid concern, but we suggest that these targets be re-examined and higher targets be considered, as this is one of the few possibilities for increased funding. The department has a considerable need for greater numbers of PhD students, so recruiting overseas PhD students with their own funding should be a priority. If the School goes ahead with a new taught Masters, then recruiting overseas students should be an important source of funding for that course. The existing taught Masters appears to be already close to the capacity set by resources, such as the number of terminals available in the room dedicated to the course, and so doesn't allow much scope for expansion. The undergraduate course offers significant opportunity for foreign recruitment, and the unique features of the course (such as advanced courses usually only offered in graduate courses) are a marketable attraction.

The recent increases in student fees in England and Wales has led to many students from there looking for better value courses overseas. A number of places in Europe (e.g. the Netherlands) are offering courses taught in English and are working hard to recruit English and Welsh students. Dublin has the advantage of having English as the language all courses are taught in, and much of its cultural heritage and way of life in common with the UK. This could make England and Wales an excellent recruitment target, and has the advantage that recruiting students from there would potentially be a better fit.

The reputation of the School and of Trinity College is a big asset in recruitment, both nationally and internationally. Some of the overseas graduate students we talked to said that they chose TCD from looking on the internet and being impressed by TCD's high international ranking in mathematics. For globalisation to

be successful, maintaining the excellence and ranking of the School are vital, and it is important that TCD make the investment necessary to sustain the high international reputation. Secondly, it is vital that the School get its message across and be vigorously promoted internationally. An important way of starting this is to do all that it can to make sure that TCD and the various mathematics courses are highly visible on the web, and take steps to get the courses to appear high in internet searches. Many overseas students will start looking for courses on-line, and ensuring the web presence is of the highest calibre is becoming increasingly important. Personal contacts, as has been seen with Tbilisi, are also very important.

In order to fully benefit from the advantage afforded by its reputation, the School should review their training provision for first year PhD students. For instance there is scope for requiring the PhD students to attend some advanced courses provided in the fifth year of a redesigned undergraduate degree.

If the School is to attract high-paying overseas students, it needs to address the issues with the leaking roof and damp etc that afflict the buildings.

7. Recommendations

(1) Pure maths should be strengthened by further appointments, filling the vacant Erasmus Smith's Chair of Mathematics and the Accenture Professorhip of Mathematics, or making two junior appointments instead of one of the two senior positions.

(2) The School should increase numbers of graduate students and postdocs, in order to achieve a 'critical mass' and foster a healthy research environment. Ideally, one would aim at one postdoctoral fellow per two permanent members of staff, and two graduate students per permanent member of staff. The Hamilton Fellowships are an excellent initiative, and should be secured, while there is scope for increasing the number of graduate students from overseas with their own funding. Increasing numbers of postdocs is much harder, but Europeans sources and philanthropic donations should be actively pursued.

(3) The reputation and high ranking of the School is one of its biggest assets. Both the School and the College as a whole should make the promotion of the School and its achievements a central focus of its publicity campaigns and fund-raising initiatives.

(4) The School should continue to address the problem of undergraduate retention. This may require course restructuring, particularly for the Junior Freshman year.

(5) A second taught Master programme in Mathematics and Theoretical Physics should be carefully considered, as it would greatly benefit the School. This requires a serious business case and a market study, and should only go ahead if financially viable in the long term. An MSc would most likely require the restructuring of the undergraduate programmes. This should be analysed together with the implications of the recent changes in the mathematics curriculum at second level, which may in any case require further changes to the undergraduate course.

(6) TCD should give much higher priority to fundraising to revitalise the Hamilton Institute, whose activities have been very attractive internationally in the recent past, and could again become a showcase for Trinity College Dublin.

(7) The dire state of the School's accommodation should be addressed, with the School emphasising to TCD the need to have world-class facilities if it is to attract international students and top researchers.

(8) The case for funding fundamental blue-skies research in science should be made to SFI and the Irish government as part of a campaign to reinstate funding for pure mathematics and theoretical physics. A concerted effort with other universities across Ireland would strengthen the argument.

(ii) **Strategic Direction**

Much of what we have to say about the future strategy of the School has already been covered in earlier parts of this review, so here we will be brief and concentrate on key issues. The School has suffered from drastic cuts in research funding and from severe Irish austerity measures, and this unfortunately limits the possibilities for any new strategy. The threats posed by these cuts should not be underestimated and a central part of the strategy should be maintaining excellence in research and in teaching. The reputation of the School is an important asset that should be safeguarded and should be a central part of the promotion of TCD in its globalisation initiatives. The cuts in research funding and in salaries can affect morale, and there is a danger that top people might leave in the future, while recruitment of staff with an international reputation could prove increasingly difficult. New sources of funding from Europe, from attracting private funding and from globalisation and the recruitment of overseas students should all be vigorously pursued. TCD has already been very supportive of the School, but, in the current absence of research funding, it may be necessary for TCD to subsidise mathematics research in the short term. It is important that TCD does all that it can to reverse the funding cuts, and in particular to make the case for fundamental research to the SFI and the Irish government.

Christopher Hull
Maxim Konsevitch
Anne Taormina

July 23, 2014

Head of School's response to Reviewer's report for the School of Mathematics

I would like to thank the review panel for the substantial time, attention and hard work they invested in carrying out a comprehensive, detailed study of Trinity's School of Mathematics. I am grateful for the friendly and co-operative environment in which the review was conducted both by the reviewers and the School staff and for the level of detail addressed in the report. The reviewer's comments are very welcome, and give in general a very supportive view of the hard work and dedication of the School's staff. It is gratifying to see the School's first-rate administrative team are included for praise.

The panel make a number of extremely positive comments that both the staff in the School and the College can be proud of. I am very happy to review the list of recommendations presented in detail and I look forward to working with staff in the School and with College to make the most of the opportunities highlighted in the report. The report makes eight recommendations:

1. *The appointments of the Erasmus Smith's Chair of Mathematics and the Accenture professorship, or filling more junior positions.* This remains a high priority for the School and will strengthen research activity in Pure Mathematics and greatly help the School plan future expansion and consolidation. After conversation with the donor, the Foundation and the Faculty Dean it is planned to readvertise the Accenture post to be filled in 2015. Filling the Erasmus Smith's Chair, which has been vacant since 2008 is of strategic importance to the School and it is expected a new Chair will bring leadership and further raise the international profile of the School. The School anticipates being able to find excellent international candidates interested in both these positions. The calibre of candidates should be maximised with support from College.
2. *The School should increase the numbers of graduate students and postdoctoral fellows.* This recommendation is strongly supported in the School and is a key to growing research activity and improving research-led teaching in the School. We note that the School has until recently had a significant number of staff on one-year contracts who could not supervise students or apply for research grants. Incoming permanent junior staff have all requested support for graduate students and the recommendation to secure funding for the Hamilton Scholarships is being actively pursued at present. Numbers of international students are growing and the School will follow the recommendations

of the review in future recruitment planning. The need to secure more income and a more sustainable funding models for postdoctoral researchers is clearly recognised by the School and will be addressed in the Implementation Plan.

3. *The reputation of the School is one of its biggest assets.* I thank the review panel for their extremely positive remark regarding our international research profile. This is regarded by School staff as an achievement of which we can be particularly proud. Recent recruitment of excellent new staff will help to secure and build this recognition. We welcome the recommendation of the reviewers that College "can and should do much more" to exploit these achievements in fund-raising initiatives and the School will continue to work towards this goal.

4. *The School should continue to address the problem of undergraduate retention.* The review highlights a concern regarding retention in undergraduate programmes and we share this concern. Changes to the national curriculum mean this is a constantly evolving topic. The School has put in place a number of supports for students including a Maths Help Room and exam revision sessions as well as new modules in practical problem-solving for JF students. We hope that these measures will help address retention issues and of course our student representatives play an active role in committees and informally in the School. The retention in Mathematics and Theoretical Physics is monitored but we note that it is not always straightforward to do since the School is not notified of students transferring out of these degrees. Finally we note that the retention rates in our degrees do not differ significantly from TR071.

5. *A second taught Masters programme should be carefully considered.* The School has already started to review this issue in some detail, since it has the potential to draw in more excellent international postgraduate students to College, in support of the College globalisation strategy. The School recognises that in order to set up a world-class programme, there are considerable resource implications that must be planned with great care. Staffing levels in the School will need to be reviewed. We look forward to working with College to develop these plans as far as possible. The reviewers' suggestion of investigating virtual training collaborations is a welcome one that we will add to our discussions. I would note that a new course provides one way of maximising the research profile of the School, as discussed in Recommendation 3.

6. *TCD should give much higher priority to fundraising for the HMI.* The long-term future of the HMI remains a concern for the School and we look forward to discussing this topic in more detail with the College, with the goal to set the HMI on a more secure financial footing. Note that this will help to maximise the profile of the research reputation of the School and substantially aid in recruitment of new staff (Recommendation 1), graduate students and postdocs (Recommendation 2) and in promoting the School and best exploiting its international profile (Recommendation 3).

7. *The dire state of the School's accommodation should be addressed.* The School agrees the building space it occupies is not fit-for-purpose, and any of the recommended expansions of research staff or post-graduate student numbers will require this serious problem to be addressed. In the short term, repairs to the buildings in Westland Row are being planned. The School will discuss longer-term solutions to this critical problem with the appropriate College authorities.
8. *The case for funding fundamental research should be made to SFI and the Irish government.* The School regards this issue as amongst the most significant challenges it faces. Before changes in policy, the School saw steady expansion in research activity as funding brought graduate students and postdoctoral fellows into the School, building the "critical mass" needed for an active research department. The policy change came essentially unannounced and has dramatically altered the landscape and morale of researchers in the School. The School sees this policy as counter-productive. Research groups had drawn in significant funds from the EU over the past decade and this activity has been jeopardised by government policy. New staff are unable to build up a profile of national funding, damaging their chances at EU level and retention and recruitment of staff will inevitably be effected. The School will work with all agencies involved to campaign for basic research to be funded by the Irish government. I fully agree that a "vigorous and sustained" campaign is needed and will ensure the School is engaged.

To conclude, I would like to reiterate my thanks to the panel for the substantial work and investment of time they made in completing their review. I am confident that we will take advantage of any opportunities presented to address the recommendations in the report and I look forward to working with the Faculty Dean and other College Officers in preparing a more detailed Implementation Plan in the near future.

Yours sincerely,

Prof. Sinéad Ryan

External Review of School of Mathematics: Faculty Dean's Response, September 2014.

The Dean acknowledges the Review Report and its validation of the excellence of the School in research and teaching, which is gratifying considering his prioritisation and support of the School over the last 6 years.

The Review correctly identifies various threats to the School and makes some recommendations to minimise them.

A key feature of the threats is the deteriorating financial situation in which we find ourselves, even though the School has been mostly protected to date from budget cuts in terms of pay and non-pay budgets. The Dean feels that this this situation will worsen for the School over the next two years.

Whereas the Accenture Professorship recruitment is ongoing, it seems unlikely that other posts will be filled in the near future unless the School's income from philanthropy and student fees can be increased by new activity.

The School does not meet its norm or targets for post-graduate and postdoctoral recruitments, and this situation is aggravated by the lack of national research funding. The Faculty and College will continue with such initiatives as the Hamilton studentship scheme and trying to get SFI funding for the academic disciplines in the School, but individual academics in the School should also be more proactive in these initiatives.

The School should investigate new Courses and improvement in existing Courses to maximise retention and recruitment. Without this new activity resources for the School will decrease rather than increase.

The Review Report makes a pertinent point about College not using the high reputation of the School in marketing and philanthropy, even though to date the School's activities has not been a priority for such activities.

Lastly the need to improve the poor physical accommodation of the School is being addressed at present.