TEN YEARS OF INFORMATION SECURITY MASTERS PROGRAMMES

Reflections and New Challenges

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Abstract: Royal Holloway launched its MSc programme in Information Security in 1992. In the subsequent ten years this programme has grown steadily in popularity, with just over 250 students registered in the current 2002-2003 session. In this paper we reflect on the apparent success of the first ten years of the programme and comment on a number of issues that we feel have wider relevance to information security education programmes in general. We also discuss some challenges facing such programmes in the future and how we propose to address them.

Key words: postgraduate training, masters programmes, programme design, industrial relationships, distance learning

1. INTRODUCTION

The developments in electronic information handling over the last ten years have resulted in an unprecedented demand for information security skills and awareness. This demand is no longer only from specialised sectors such as defence and finance, but it is now coming from all business environments, public sector organisations, government departments, and to a certain extent from private citizens themselves.

Royal Holloway, University of London, launched a postgraduate Master of Science programme in Information Security in 1992, and has witnessed the results of this change in the profile of the subject over the subsequent decade. This paper is not concerned with the drivers for such change, which

should be self-evident, but with the ways in which higher education programmes can best try to embrace and satisfy the demand for information security skills.

We will first present some background to the development of our own programmes in information security. We will then look at a number of programme design decisions that we have faced and that we feel have relevance beyond our own borders. We end by taking the opportunity to discuss several breaking issues and challenges that we feel need to be addressed to meet future needs for postgraduate information security education.

2. INFORMATION SECURITY PROGRAMMES

In this section we will examine the current situation on our own information security programmes. We will go on to discuss a little bit about the background of students on these courses and then look at relevant growth patterns.

The interest in information security at Royal Holloway grew out of a strong research base in cryptography, stemming from the academic interests of individual academics within the Mathematics Department. In 1992 the formation of the Information Security Group (ISG) formalised a broadening of the research focus across both Mathematics and Computer Science. The ISG launched the MSc Information Security in 1992, the first postgraduate qualification of its kind in Europe, and it is now in its eleventh year. In 1999 the ISG, now an autonomous group, launched a second related MSc in Secure Electronic Commerce.

2.1 Current Range of Programmes

2.1.1 MSc Information Security

This is an advanced MSc degree that is designed to introduce the technical, legal and commercial aspects of Information Security. The degree is intended as a foundation for a professional career, as well as for postgraduate research. Graduates of the degree are expected to find employment in both industry and commerce as security experts.

The MSc degree is taught in course modules. Each module usually consists of thirty-three hours of lectures (three hours per week for eleven weeks), sometimes with tutorials and practical work. The curriculum for the MSc degree consists of six taught modules and a project. Of the six taught modules, four are mandatory core modules and the other two are optional

modules chosen by the student from a list of options. Alternatives to the standard mode of delivery are currently being developed (see Section 4.1).

A list of the modules for this programme are shown in Tables 1 and 3. Full details can be found at [3].

2.1.2 MSc Secure Electronic Commerce

This advanced MSc degree has very similar aims and intentions as the MSc Information Security, but has a slightly different focus. The main differences are that whole core modules are devoted to business issues and the law, with a reduction in the amount of technical content. The structure of both MSc programmes is identical, with most of the optional modules shared between the two degrees (see Tables 2 and 3).

Table 1. MSc Information Security Core + Specific Option

IC1	IC2	IC3	IC4	OPT5
Security Management	Introduction to Cryptography and Security Mechanisms	Network Security	Computer Security	Secure Electronic Commerce and other Applications

Table 2. MSc Secure Electronic Commerce Core + Specific Option

SC1	SC2	SC3	SC4	OPT6
Business and Security Issues	Introduction to Cryptography and Security Mechanisms	Secure E-commerce: Infrastructure and Standards	Legal and Regulatory Aspects of Electronic Commerce	Current Developments in Secure Electronic Commerce

Table 3. Options common to both MSc courses + Compulsory Project

OPT7	OPT8	OPT9	OPT10	
Standards and Evaluation Criteria	Advanced Cryptography	Database Security	Computer Crime	M.Sc. Project

2.1.3 Postgraduate Diploma

The ISG, in co-operation with QCC InfoSec Training Ltd, also runs a postgraduate diploma that is intended for students who do not have the time to attend a whole MSc programme. This consists of a number of short courses, supplemented by the writing of three essays and a project. The focus of the diploma is more on training than on comprehensive education.

Currently there are over 60 registrations. The diploma is particularly popular with students who wish to study over an extended time period.

2.1.4 Other Programmes

The ISG has a large PhD programme, with almost 40 students currently registered. We also run specific information security training courses on demand.

2.2 Student Background

Students on the two MSc programmes at Royal Holloway come from a variety of backgrounds, including both management (business and economics) and technical (information sciences, computer science and mathematics). Part-time students, who take the degrees over two years, have been particularly encouraged to apply. We are willing to consider relevant industrial experience as a replacement for conventional academic qualifications on our MSc programmes, and regularly accept high quality students with industrial backgrounds onto the programmes. Although management students tend to find the technical aspects of the programmes initially challenging, the provision of background classes and tutorial support tends to bring them up to speed.

Most students on the MSc programmes fall into one of the following three categories:

1. Recent graduates: students fresh from an undergraduate degree who wish to spend a year engaging in further specialisation.
2. Sponsored students: part-time students currently in employment within the I.T. sector (but occasionally full-time students on year-release) whose employers are at least partially supporting them in their studies.
3. Career changers: mature students, often with extensive I.T. or business experience, who are seeking to update knowledge or seek fresh career opportunities.

Sponsored students and career changers have joined the programmes from many different industrial sectors, including hi-tech companies, military, government, public services, financial organisations, specialist security companies and telecommunications.

Both MSc programmes have proved very attractive to overseas students. To date students from almost 40 different countries have completed one of the two programmes, with around 20-30% of students in a typical year coming to Royal Holloway from outside the European Union. Within the E.U. the programmes seem to be particularly popular with students from Greece, Germany and Ireland. Beyond the E.U. we have had significant

numbers of students from China (mainland and Hong Kong), Japan, Korea, Malaysia, Singapore and Taiwan. Most years we have several students from the United States. Currently we are seeing a big increase in interest from Central and South America, India, and the Middle East.

2.3 Growth Patterns

The number of students attending the two M.Sc. courses at Royal Holloway is shown in Figure 1.

Figure 1. Numbers of students attending Royal Holloway MSc programmes

Although the upwards trend in the total numbers of students attending Royal Holloway MSc programmes is to be expected given the technological developments during the period over which the programmes have been running, the continual steady increase in interest in such programmes has surprised us. Numbers may currently be “artificially high” on the MSc Information Security due to the present downturn in the I.T. sector resulting in an extra demand for retraining. The reverse in fortune of the MSc Secure Electronic Commerce is almost certainly due to a “branding problem”

following the failure of “e-commerce” to live up to much of its anticipated hype (we discuss this issue in Section 4.3). Nonetheless the growth in total numbers provides strong evidence that interest in postgraduate qualifications in information security is still high, and likely to remain so for the foreseeable future.

3. PROGRAMME DESIGN ISSUES

We now review a number of programme design issues that we feel have been influential in the planning of our MSc programmes. We do not claim to have got any of these exactly right, but the current success of the programmes suggests that at least some of the decisions that we have made must have been fairly sound. We will also reflect on some decisions that we perhaps did not get quite right.

3.1 Involving the Information Security Industry

The MSc programmes at Royal Holloway are heavily influenced by the requirements of the information security industry and the ISG works closely with industrial partners to maintain the standards required in the workplace. This is done in a number of different ways.

3.1.1 Programme Planning

From the very first stages of planning of the MSc programmes, the ISG has worked very closely with the information security industry to make sure that the learning outcomes of the degree programmes closely match the professional security skills that are required by employers. From the outset, the basic structure of the MSc programmes was widely discussed with more than thirty institutions; these included government departments, large IT companies, and many financial organisations. This exercise has ensured that the overall structure of the MSc remains stable.

3.1.2 Curriculum Development

To ensure that the course is completely up to date, many of the modules involve significant input from recognised security experts from industry. Furthermore, all of the academic staff have links with external organisations that are involved with information security and secure electronic commerce, including many of the largest such organisations in the country.

The courses are also overseen by a Steering Committee that consists of the members of the ISG as well as a number of visiting professors that include some very influential experts from industry. Although this latter group has no formal powers their opinions are highly regarded and all their suggestions are therefore taken very seriously and acted upon.

3.1.3 Teaching

The ISG makes quite considerable use of presentations by security industry experts on a number of modules. The use of external speakers is normally made when

- The topic does not lend itself to an academic treatise and is most suited to presentation by a practitioner (this applies to areas such as e-business security and security management).
- The topic contains significant amounts of specialised state-of-the-art material that is either not accessible to academics, or is more readily available from practitioners active in industry research forums or development projects.

The involvement of security professionals in the delivery of course material has a number of significant benefits for all involved parties, some of which are not immediately obvious:

- Involving security professionals in the course helps to cement the relationships between Royal Holloway and external organisations.
- Students benefit by having direct access to practitioners.
- External organisations gain exposure to a specialist recruitment base.
- Students and security professionals both have the opportunity to establish industrial project placements
- Most security professionals thoroughly enjoy coming to Royal Holloway and often comment on the thrill they get from exposure to a security aware audience who often ask thought-provoking questions.
- In our experience (and often in contrast to University management expectations), most of our selected security professionals are outstanding speakers who deliver careful and relevant presentations.

There are of course a number of drawbacks to using external presenters, which need to be carefully managed:

- It is not always easy to control the content of a presentation by an external speaker (we overcome this by careful selection of presenters).
- It can be difficult to provide context and structure to a module that heavily uses external speakers (we address this by careful design of each lecture programme and, if necessary, outside the lecture environment by the provision of supplementary material).

There are in fact two entire modules whose subject areas are so specialised and beyond our academic skills base that we contract them out to ISG consultants. These concern Computer Crime and Legal Aspects of Secure Electronic Commerce. It is questionable whether we would offer these topics within the MSc programme if we were restricted to use of our own internal knowledge base, and there is no doubt that the programmes would be weakened by their exclusion.

3.1.4 Establishing and Maintaining Industrial Relations

In our opinion, the success of our programmes has largely been based on our strong relationships with the local information security industry. Establishing and nurturing such relationships is not an easy task, and this has been an ongoing and intensive priority of the ISG since its inception.

While individual personalities and involvement in projects have played a considerable part in this success, we cannot ignore the role of geography in establishing the ISG as an information security hub within the U.K. Proximity to London itself, and to London Heathrow Airport, has made getting to Royal Holloway a relatively straightforward exercise for anyone based in, or visiting, London or the South-east of England, which is home to a considerable percentage of both the U.K. population and business headquarters of U.K. organisations. (The same argument also applies to the ability of the programmes to recruit part-time students on day-release from places of employment.) This has even facilitated some part-time students to “commute” from Belgium, Denmark and Italy to attend our MSc programmes!

The MSc programmes are now also a major source of further industrial links as our growing alumni find employment in the information security industry throughout the world. The ISG continues to nurture its industrial relations through its web page, alumni mailing lists and further networking activities such as informal dinners.

3.2 Getting the Syllabus Balance Right

Deciding exactly what to include in a Masters programme in Information Security is not easy, as the subject spans a vast number of wide ranging and disparate disciplines. In particular, getting a suitable balance between technical issues and business/management issues is a major challenge.

The approach taken by the ISG at Royal Holloway is largely an accident of circumstance. Due to its origins as a centre for cryptographic research, it would seem inevitable that an ISG hosted programme would have a technical bias. However, from the outset the ISG recognised that such an

approach would neither be likely to attract a large number of students nor supply the needs of the information security industry at large.

As a result we have tended to adopt an approach of teaching technical material in house, and inviting external input in order to cover business and management issues (see Section 3.1.3). This seems to work quite well because technical topics lend themselves well to a single integrated approach, whereas the ambiguity of many management issues are more suited to a diverse coverage from different voices and business environment perspectives.

One interesting development that reflects the fragility of this balance concerns the core module on Cryptography and Security Mechanisms. Many students from non-technical backgrounds commence their MSc programme by regarding this module with considerable trepidation. However, the result of teaching cryptography to students from diverse backgrounds for ten years has been that the focus of this module has drifted considerably from technical details to management issues. In fact this module is now a non-technical cryptography module - a concept that some students, and academics, sometimes have trouble comprehending! An optional module on the technical aspects of cryptographic algorithm design now balances this shift in emphasis.

3.3 Encouraging Student Diversity

Another area where we feel that our current programmes have gained strength over the years has been in the participation of students from wide ranging backgrounds. This has acted as a strong area of compensation at a time when increasing numbers of students have inevitably resulted in a less personalised learning experience for students following the programmes.

We have encouraged diversity of experience within the student community by:

- Developing a programme structure that is particularly suited to part-time students, by concentrating lectures on certain days of the week to facilitate study by means of day release.
- Supporting applications from high quality (mature) students with relevant industrial experience, irrespective of whether they have previous academic qualifications.

In Section 2.2 we noted that students on the programmes typically fall into one of three categories. While "recent graduates" are often academically strong, they typically lack the practical or industrial experience of "sponsored students" and "career changers". This results in a student community with mutually compatible skill sets, and by encouraging the students to form informal study groups as well as to participate in organised

course activities, we try to foster an environment in which these different student communities can interact and share their skills and experience. This seems to us particularly important in a discipline such as information security, where there are rarely any “correct answers” and where opinions and debates can be just as insightful as the relevant facts.

3.4 Hands On or Hands Off?

There is no doubt that it is desirable to provide a practical component to any information security qualification. While theory is arguably longer lasting and of greater significance, it is most certainly enhanced by practical “hands on” sessions, regardless of how ephemeral the technology on which it is demonstrated may prove to be. There is also no doubt that providing such a component is incompatible with supporting large numbers of students on a taught programme. This is one demand that our current approach cannot satisfy.

However it is interesting to report a fairly commonly observed pattern in student response to our openly “classroom-based” approach to information security training (it should be noted that this pattern relates only to the minority of students who comment on the theoretical bias to the course). Students typically start with an open mind, but then as they learn about various technologies it is common for a minority of students to express a desire for more “hands on” access to technologies. While we do our best to facilitate such a demand (such as running hacking courses and firewall configuration sessions) we notice that this demand often falls away as students realise the sheer mass of material that they need to cover to satisfy the programme. By the end of the course they tend to be satisfied with the overall balance and have recognised the difficulties that greater access to practical work might have involved.

It is also worth emphasising that as with most academic courses, as well as knowledge transfer, successful students should complete the course with a number of transferable skills in the area of learning, information processing and report writing. Many employers regard these as more important than extensive practical experience.

We are continuously seeking new opportunities to provide managed practical sessions. Currently we are developing a penetration-testing laboratory where students can experiment with various tools within a localised and controlled environment. We are also developing a smart card centre where students can get more closely involved with projects relating to security hardware tokens. Students with a keen desire for “hands on” are also often encouraged to pursue a practical MSc project. However we do recognise that on this issue we are responding to our constraints rather than

to some notion of an ideal course. We believe that our current approach is the most suitable one to follow with the large student numbers that are attracted to the programmes.

3.5 The Shifting Syllabus

Probably the major challenge faced by any courses attempting to provide a comprehensive overview of information security issue is the problem of the shifting syllabus. The developments over the last ten years in this area have been dramatic, and during the typical running schedule of a course module (in our case eleven weeks) there is very likely to be at least one or two developments that have the potential to impact module content.

The challenge is of course to harness these developments and use them to enhance the learning experience, rather than to view them as potential obstructions. Including real time incidents and contemporary events as illustrative examples is greatly appreciated by students. The only difficulty is keeping abreast of developments in order to accommodate the latest information.

There are a number of ways in which we try to do this at Royal Holloway:

- External speakers: the use of external speakers on some modules does bring in the latest information from people who are often at the “coalface” of developments in their particular field.
- Optional seminars: each semester we run a series of optional seminars, which can be used to plug syllabus gaps should issues arise during the year that are not adequately covered by the main syllabus.
- Mailing lists: we provide open access to several student mailing lists, which allow staff, current students and alumni to post relevant links and articles concerning breaking issues.
- Using news stories: several of the modules on the MSc programmes incorporate current events directly into their syllabus by requesting comment on newspaper/magazine articles (for example).

In addition to a “running review” of the programme syllabus, most modules need to undergo an annual retrospective review process, where content is updated and amended for the following session. As a rough estimate, we plan for a syllabus change each year of approximately 10% per module. Obviously this varies depending on the module content. The Cryptography and Security Mechanisms module, for example, is reasonably stable. The Computer Security module has a stable theoretical core that has been designed explicitly to be as timeless and technology independent as possible, however application security topics change on an annual basis. Current Developments in Secure Electronic Commerce, in contrast,

undergoes annual reviews that can lead to changes in up to 50% of the module content, depending on what issues have emerged and which have faded over the previous twelve months.

3.6 Scalability

The issue of scalability of a postgraduate course is one that we feel, retrospectively, we perhaps did not get quite right. While in 1992 the ISG recognised the potential demand for information security postgraduate education, the expectation (and initial reality) was of student numbers of around 10-20, not 100-200. A number of problems have arisen from the rapid increase in student numbers:

- Timetabling issues: One feature that was built into the programme that made sense initially, but now pose restrictions on current operation is our “bundling” of modules together to allow part-time students to only attend on certain days of the week. Since there are now significant numbers of students, many of whom are attending over two years, we have found it very difficult to make any timetabling adjustments and find ourselves restricted to the initial course timetable that we offered in 1992. This restriction makes it particularly difficult to make changes to the ways in which the core modules are offered on campus.
- Impacts on staffing: The format of the MSc programme, particularly the existence of a significant project component, has resulted in considerable pressures on staffing resources throughout the twelve months of the year. With a couple of dozen students it is possible to arrange emergency supervisory cover over the summer months, but with approaching 200 students this becomes much harder. Although the ISG has been permitted to recruit extra staff in the last three years, there are still very high demands placed on the current staff. This puts inevitable pressures on research time, and has also made it very hard for research staff to take sabbaticals. Had it been possible to predict the demand, we might have been able to plan staffing resources more effectively.
- Impacts on the student experience: The classroom-based approach to teaching the main syllabus material (formal lectures and supporting tutorials) has also probably suffered by the increase in numbers. Quite simply, lectures become more formal and it becomes less possible to offer quality staff-student time with larger student numbers. Of course this problem is offset slightly by the greater capability for active study groups and peer learning to take place amongst the students themselves.

4. FUTURE DEVELOPMENTS

Given the speed at which developments in information security take place, it does seem at times that operating information security educational programmes is an exercise in “running to stand still”. However, as well as keeping track of future syllabus content, there are a number of other issues that we feel are important to address in order to maintain our claims to meet the training needs of the information security industry.

4.1 Flexible Learning

A major area of development at Royal Holloway is to try to meet the needs of future learners, especially those whose geographical and financial constraints limit their ability to attend a campus in the U.K. for several days a week over the period of one (or two) years. There are two major initiatives underway, both driven by direct demand, which we hope will result in a more flexible programme that will open up our programmes to new student markets.

4.1.1 Distance Learning

We are in the process of “converting” our MSc Information Security into distance learning format for remote delivery. The initiative is backed by the External Programme of the University of London [1], who have extensive experience of delivering paper-based distance learning degree courses. This programme is going to be launched in September 2003 and includes the following features:

- Course content is presented using a mixture of interactive web pages, audio recordings and reading resources.
- Courseware will be delivered in electronic form, either through CDRoms or web downloads.
- Students interact with courseware through a custom built virtual learning environment.
- Students are supported online via electronic offline seminars (bulletin boards) and email support from course tutors.
- The course is structured identically to the campus based MSc and students assemble their degree on a modular basis.
- Students will be examined using the External Programme’s worldwide network of examination centres and will sit examinations of identical standard to the campus based MSc programme.

The distance learning programme comes with its own set of challenges. These include:

- Finding qualified support. Providing qualified support for distance learners in a specialist area such as information security is not particularly easy. Such support is needed to manage the running of a distance learning module, to moderate online discussions and to support the extra work generated by assessment and project supervision. Academics within the ISG could provide this support, but are already stretched in workload and so such an expansion of our programme involves finding extra assistance. We are currently looking into the involvement of alumni and security professionals in these activities.
- Updating material. Given the annual turnover in syllabus material described in Section 3.5, keeping distance learning material up to date is likely to be very challenging. It is inevitable that distance learning courseware may lag behind some of the content delivered on campus, but on the other hand the resource base of learning materials developed over time may well compensate for this.
- External presentations. For topics such as security management, where we make heavy use of external speakers on the campus course, creating suitable distance learning material is challenging. Our current approach has been to take the best of the campus presentations and present them as “supported audio lectures”, where PowerPoint slides, audio clips and supporting text / exercises are blended into a multimedia package. For some learners this may even be a preferable experience to sitting in a live presentation, however student feedback on using these materials is not yet available.

4.1.2 Intensive Modules

Another direction we are starting to move in is to provide certain modules in more intensive formats. Rather than attending an entire module on campus on day release, students would attend several intensive sessions (possibly lasting several days). Where numbers of students from an external organisation or from a specific geographical location are sufficiently high, we also intend to offer these intensive modules on site.

This is essentially an alternative format for part-time students, and recognises that fact that different organisations prefer different types of schedule concerning the release of employees for educational courses. Such intensive modules of course still need to be supported over a longer period.

The main drawback with this format is that it is only appropriate for modules that are entirely taught “in house”. For this reason we anticipate that students preferring intensive modules will be required to assemble their final

degree by also “attending” modules delivered either on campus or at a distance. The details of how this might be done in practice have not yet been fully worked out, but we are convinced that flexibility of delivery is going to be a high priority for future information security students, and that programmes will need to match this demand if they are to be successful in tomorrow’s higher education market.

4.2 Professional Qualifications

The increasing interest in information security has led to a proliferation of professional qualifications in this area, which clearly is something that academic institutions need to monitor. We have been particularly interested in the increased profile of the CISSP qualification from (ISC)² [2]. CISSP is an interesting example because there is some considerable overlap between what is offered by this qualification and what is offered within the ISG. The CISSP qualification requires that the individual have four years of relevant industry experience and that they have performed well in an examination. They also need to maintain their qualification by completing accredited course work. The scope of examinable material is probably about the same as that offered at Royal Holloway, although the depth of coverage by the ISG is much greater and the CISSP does not have a project requirement.

Rather than being regarded as “competitors”, a CISSP qualification and an MSc from Royal Holloway appear to complement each other very well. It is the practical experience that some view as being lacking from the MSc’s, yet it is this practical experience that the CISSP qualification claims to recognise (exactly how such industrial experience can be quantified is a difficult issue that we have also encountered during our admissions selection process). We have been investigating the possibility of exploiting this synergy between the MSc and the CISSP qualification and hope that it may be possible to offer some arrangements in the future that will facilitate some students obtaining both qualifications. We will also be watching carefully the development of other related professional qualifications.

4.3 Tomorrow’s Programmes

The demand for higher education information security training that we have experienced suggests a preference for general programmes that equip students with a solid grounding in issues across different business sectors, but we believe that there is also a demand for more specialist training targeted at precise industries.

In 1999 we launched our MSc Secure Electronic Commerce, in response to the rising demand for direct training relevant to this area. As can be seen

in Figure 1, this course was extremely successful from launch, but suffered a significant downturn in student numbers in direct response to changes in the fortunes of fledgling “dot.com” businesses. It would seem likely that other information security topics may lend themselves to short term increases in demand, however it does not seem justifiable to launch programmes to meet needs that may turn out also to be rather ephemeral in their high levels of demand.

We are currently reviewing the status of the MSc Secure Electronic Commerce programme, which in our opinion remains a viable and attractive degree, but may have to be restructured and perhaps re-branded. (It is worth noting that a taught Masters programme with over 20 full-time students is not normally regarded in U.K. universities as a “failure”!) Part of the current curriculum review process is also looking at information security specialisations that may have a more stable future, such as secure telecommunications.

5. CONCLUDING REMARKS

We have reviewed some of the issues that we feel have arisen from our ten years of experience of delivering postgraduate MSc courses in information security. We have had a very positive experience of involvement in this area over the last decade, but recognise that success can only be maintained by hard work and constant retrospective review. If we had to identify one area on which to concentrate when designing information security programmes it would certainly be involving the security industry throughout the process of creating and delivering courses. While information security is an academic discipline in its own right, it is more importantly a practical topic, whose skills are in high demand. Meeting those skills in the future may need a re-assessment of the ways in which course content is delivered to students, and we believe that they key to continued future success will be the ability to deliver programmes in as flexible and adaptable a manner as possible.

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