

Introducing Research Methods to Computer Science Honours Students

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Abstract

Research skills are important for any academic and can be of great benefit to any professional person. These skills are, however, difficult to teach and to learn. In the Department of Computer Science at the University of the Witwatersrand we have for a number of years included the completion of a research report as part of our Honours programme. This paper is a case study of how we have implemented an introductory research methods Honours course to increase our students' exposure to research and to help them cope better with their research reports. This course provides an effective way of introducing research to a relatively large class of Honours students. It is now being given for the second time. Our experience with the course is positive and we believe it has made a major impact on the way research is done by Honours students. Many of the problems we encountered with the Honours research reports prior to the introduction of the research methods course have been alleviated.

Keywords: *computer science education, research methods*

Computing Review Categories: K.3.2

1 Introduction

The ability to do research is an extremely important attribute for any academic. In fact, research skills can be of great benefit to any professional person. In the Department of Computer Science at the University of the Witwatersrand we believe that our graduates need to develop an understanding and appreciation of research. Our approach to this has been to replace practical projects with research reports in the Honours year (fourth year) and for a number of years have included the completion of a research report as part of our Honours programme. In this way we hope to develop academics as well as provide highly educated graduates for industry and commerce.

In 1997 we decided that our students needed to acquire certain research skills in order to more successfully tackle the research report. It is unreasonable to expect students who have been focusing on dealing with lower-level concepts and principles to be able to immediately pick up the very different skills required to do research. Students need to adjust to an important new paradigm in their educational experience which shifts the focus from answering focused questions to taking responsibility for presenting a well argued thesis. For a reasonable sized class of seventeen to twenty Honours students, it becomes worthwhile to provide a course on research methods to help the students to come to grips with this new educational experience. Thus in 1998 we included an Introduction to Research Methods (IRM) course in our Honours programme and repeated it in 1999 with a different lecturer.

We believe that this course plus the Research Report (RR) component of the Honours degree gives our students

a very valuable introduction to research which will be of great benefit if they are going on to a higher degree in computer science and also will assist students who do not continue their studies. Specific benefits which we see are that doing these research courses could encourage students to do a higher degree but even if this is not the case they will learn to read and understand scientific papers, learn to argue logically and coherently and improve their writing and presentation skills.

This paper discusses our motivation for IRM (Section 2), what we believe are the skills needed to do research (Section 3), the aims and objectives of IRM (Section 4) and the approach that we have taken to teach these skills to our students (Section 5). In Section 6 we discuss some of the results of teaching this course in 1998. An earlier version of this paper appeared as [2].

2 Motivation

For a number of years our Honours programme consisted of 8 lecture courses, a self-study and a research report. The selection of courses offered in any year contains some courses which we have defined as being *core*, while the remainder of the courses depends on the interests of staff available. The self study was used as a vehicle for covering some material not covered in the other coursework. It has also been a vehicle for the students to undertake individual learning and to practise their reading and writing skills. The aim of RR is to give the students the opportunity to develop an understanding and appreciation of research.

Over the years, though the final research report pro-

duced was, on average, of a high quality, we experienced a number of problems with the process, many of which we ascribe to the students' lack of understanding of research methods when they start.

Traditionally, students learn research methods by doing, by being supervised on a particular project, and by trial-and-error. There are advantages to this process, but it has several problems. It discourages students from reflecting on what they are doing; they become focussed on system building—thus the students can only learn methods of research unconsciously and through osmosis. The initial phase of research can be particularly difficult: deciding a suitable question, choosing a scope of an appropriate size; and developing a method of answering the question.

We found that our students started their research without understanding what research means and what our goal is. Although making mistakes is one way to achieve learning, in the limited time that the students had for RR this was not an effective approach. Examples of symptoms of this problem were that the research question was a statement of a system that the student wanted to build, the scope of the research was far too big, and the initial proposal often did not have a plausible methodology for solving the problem. In addition, students did not know how to use the literature effectively.

The consequences were deadline slippage as students floundered, frustration on the part of students, costly mistakes, increased demands on staff supervision time, extra work for students, and in many cases an end product that was not as good as it could have been.

We believe that many research skills can be far more efficiently and effectively acquired by undertaking a series of small, guided exercises and readings that deal with issues ranging from philosophical questions of the nature of research to nitty-gritty issues like how to cite papers, leaving the students far better equipped to undertake their research. We thus decided to replace the self study with a course focussed on preparing the students for RR but also giving them wider exposure to research methods and research topics.

A problem we encountered was a lack of material on research methods that relate specifically to computer science research. Research in computer science appears to have some significant differences to traditional forms of research, either in the natural or social sciences. This means that we had to tailor a course appropriate to the discipline. The next section of this paper discusses the competencies which we feel are necessary to successfully undertake research and Sections 4 and 5 discuss IRM in more detail.

3 Skills needed to do research

Traditionally, becoming a researcher has had similarities with an apprenticeship—through association with a supervisor the student is exposed to the methods and process of research. Rudestam and Newton [7] describe the dissertation process as a ritual of socialisation into the commu-

nity of scholars, but preparation for research can go beyond this, and there are clearly identifiable competencies that will be of use to any researcher.

Phillips and Pugh [6] describe research as a craft, hence the basic educational process involved is learning by doing. They argue that no relevant procedure, skill or technique should be used for the first time in the thesis project, but should have been practised beforehand. They speak specifically about doctoral research, but the same general principle applies to all postgraduate research. In general, one can't make students into researchers, but one can give students the exposure, the skills and the tools needed as part of being a competent researcher. Hence a desirable goal is to give the students opportunities to develop and practice a range of research related skills such as:

- critical thinking
- the ability to find literature in libraries, on-line databases and on the WWW—this includes appropriate search strategies.
- critical reading as well as quick evaluation of the relevance and value of other research
- the ability to summarise and capture the essence of a piece of research
- the ability to see the similarities and differences between two pieces of research
- the ability to present a logical and coherent argument
- identification of what a research question is and the development of realistic and testable hypotheses from this question
- presentation skills, since research is of no use if it is not communicated.

Beyond these skills, there is certain knowledge which is valuable to students and will help them during the process of research:

- an understanding of the different types of literature, and how much importance to assign to it
- an understanding of the complexity of choosing and applying experimental and statistical techniques
- an understanding of the scientific method and how it can be an unreachable ideal, and that research is not necessarily the smooth, tidy process described by the scientific method
- an understanding of different research methods
- an understanding of research in computer science and how it can differ from traditional forms of research. Some computer science research uses methods from the social sciences (such as computer science education), some research uses proof, and yet other research appears to be in a distinct category where test cases (which are justified) are used to test a hypothesis.

Furthermore, there are important tools which should be introduced, such as tools for literature search (collections of abstracts, on-line databases and the WWW) and also research-oriented document production software (\LaTeX and BibTeX).

4 Course aims and objectives

The overall aim of IRM is to start the process of introducing students to research methods (the process is continued in RR). IRM is designed to give an initial exposure to the skills discussed in Section 3. This is achieved by working through various stages of the research process. The specific aims of the topic are to assist students to

- develop an appreciation for research and an understanding of the nature of research
- develop the ability to make a logical argument
- be able to critically evaluate scientific literature
- develop an ability to synthesise knowledge from a number of sources
- be able to understand the nature of a research problem
- improve their reading, writing and presentation skills.

By the end of IRM, we expect the students to meet the following objectives. They should be able to

- understand a paper of moderate difficulty
- find material related to a research topic
- comment on and identify the strengths and weaknesses of a paper
- write a review of the literature on some topic
- present a hypothesis for testing, decide how to test it and design an experiment to test it
- write a research proposal.

5 Teaching the necessary skills

The course is structured in such a fashion that the students work through steps of the research process with constant feedback and assessment. We have set the course up so that one member of staff is in overall control of the course and is responsible for most of the assessment but other members of staff contribute to various of the tasks and are involved in giving feedback to the students. The various tasks which the students work through are outlined below.

- The students attend lectures (where class participation is encouraged) and are given reading as an introduction to research methods. They are tested on the material covered in the lectures and in the reading. This runs throughout the course. Some of the books used for reference in this phase are Leedy [4], Dominowski [1] and Meyers and Grossen [5].
- The students do small group work during class involving data analysis and data collection techniques.
- They are given a computer science survey paper which they are expected to work through (in collaboration with their classmates) until they fully understand the material covered in the paper. They are tested on the material covered in this paper.
- They are given two papers on a very similar topic and are expected to compare and contrast them.
- They are given a paper which they are asked to read, understand and then present to their classmates.

- They are given a list of references on a given topic and are expected to find the papers and prepare an annotated bibliography of the papers. Members of the department provide the topics and comment on the final documents.
- They are given a number of papers and asked to do a literature review of these papers. Again staff members offer topics and comment on the students' work. The students also present their literature reviews.
- They consider various research hypotheses and how to test them. They also work through the process of formulating and testing hypotheses for focussed research problems.
- They are given a research report written by a previous Honours student to review.
- They prepare a prototype research proposal based on a given literature survey.

Each of the above tasks can be related back to the skills, knowledge and tools in Section 3. The knowledge items are covered during the lectures and small group work, with reinforcement during the assigned work. Critical thinking is an important aspect of both our undergraduate and Honours degrees, and it is not emphasised any more than usual in this course. The ability to find literature is exercised during the annotated bibliography and literature review phases, and the students are given an introduction to various databases by the library staff. This also gives experience in the use of search tools.

Critical reading is important for most of the work done in the course, as the students are required to read with thought before taking an assigned piece of work further. Summarising is dealt with during the annotated bibliography, and comparison is dealt with in two assignments—the comparison of two papers and the literature review. The generation of hypotheses and research questions is dealt with in the hypothesis stage and in the prototype research proposal. The argument and presentation skills are emphasised whenever the students produce documents or give presentations. Although not compulsory, we also encourage students to use LaTeX and BibTeX, and for some phases, provide document templates from which they can work.

As can be seen by this, the course is structured to deal with each skill at least once so that the student can gain experience. In addition, because the students read numerous articles they are exposed to different forms of research—this was not the case in the past.

The students are encouraged to discuss any problems they have with the lecturer, and feedback is an important part of the whole process. Students receive both individual feedback, as well as a summary which is sent to the whole class highlighting issues relevant to a number of students.

RR then allows the student the opportunity to further practise the skills that they have learned in IRM by going through the full research process on a small contained problem.

6 Evaluation

Unfortunately as with many educational innovations, much of the initial evaluation of the new course is anecdotal, especially as we have relatively little hard 'before' data and it is very difficult to set up any controlled experiments. We plan to survey this year's Honours class after the completion of RR and believe that this will give us some useful feedback. The rest of this section discusses our experiences of the course to date.

6.1 Experience teaching IRM

The course is a challenging one to teach. It takes time to choose appropriate materials that will fulfil the objectives, and both lecturers have not been completely satisfied with their choices. We do, however, feel positive that the students are benefitting even if the choice of materials is not 'perfect'. The course also requires a great deal of regular assessment and feedback to the students. The nature of the work means that this assessment and feedback is very demanding on the lecturer's time—the marking is both intense and difficult.

It is, at times, difficult to convince the students that this course is as important as the other lecture-based subject-specific courses and sometimes they do not work as consistently as we would like. This is clearly something that we have to apply our minds to for the future. We feel that this issue can at least to some extent be addressed by all members of staff being involved in and supportive of the course. Certainly there was more staff involvement in 1999 than 1998 and the students seemed to appreciate this.

It is an enjoyable course to teach because of the opportunities for interactions with class, particularly during the lectures; and for discussions with students about aspects of research. It is also a very rewarding feeling to see their presentations improve as the course progresses and also to note improvements in writing style.

We also feel that it is an important opportunity to let students know of the possibility of further research-related study such as research degrees, and to encourage students to study further. This is something which our earlier style of teaching research did not offer.

6.2 Impact on the Research Report

The first place where benefits from IRM may be seen is RR which students complete after IRM. RR consists of several phases and milestones, the most important of which are the research proposal and final document. These research reports are conducted under the supervision of a member of staff and the major documents are also read by a second member of staff. There is also a member of staff who acts as coordinator for RR and is responsible for the overall marking and running of the process.

The process of conducting the research reports in 1998 appeared to be much smoother than in previous years (though the 1998 class was also smaller than the classes we

usually have). It was noticeable that there were far fewer serious problems than in the past, and the serious problems that did exist were attributable to other factors (e.g. a supervisor being away at a critical time, or the student not doing any work). On reflection, both from the supervisors' and the RR coordinator's view points the process was much smoother. The positive aspects were:

- The proposals were on average better, with greater focus and understanding of both the form and content of what a proposal should contain.
The students appeared to have a greater understanding of what research was about. They all—even the worst—understood that they needed to have a proper research objective and this understanding was reflected in the considerably better sections which discussed their research objectives and contributions.
- The students' ability to use the literature was better. They started their research with an understanding of the different types of resources, where they could be found and how they should be analysed. There was still a tendency for literature reviews to be a list of brief summaries of papers, but on the whole the reviews were more integrated and critical.
- There was a better understanding of the need to do a proper evaluation. From the beginning students knew that they had to have a proper method for answering a research question. What was quite striking were the debates that the RR coordinator had with a number of the students at various phases about what type of data was required to answer a question and how the data should be analysed. These discussions showed a greater insight into the process of research than had been displayed in the past.
- Related to this, students had an understanding of the research report as a process and not just as an end in itself.
- As students had a better insight into the process, supervisors could spend more time with students on the particular problem, rather than on the process. For example, as students had some understanding of what was required in a literature review, supervisors could focus on the particular literature review the student was writing, rather than the general principles of what goes into a literature review.
- The general standard of the reports as documents presenting the research was better.

6.3 Pragmatic issues

The lecturer in charge of the course has to put significant work into the course, and some involvement from other staff is required. While not a very intensive course for staff, it cannot be done on the cheap, and the staff member who does the work has to get proper credit. Our estimate of the work required for a class of 18 students in 1999 was that the lecturer responsible would have to spend 220 hours in total (with an additional 70 hours because the lecturer is

new to the course). Part of this is a shift in workload as previously the place in the curriculum was used for a self-study project where individual members of staff supervised students. However, it does appear that overall the introduction of this course has increased the workload slightly.

One negative effect of introducing IRM is that the time available for RR is reduced. This put increased pressure on the students and shortened the time from the start of the research to its conclusion. There was some disagreement among academic staff how serious the first problem was, but there was general consensus that the time available for RR was not sufficient. In 1999 we have tried to address these problems by slightly reducing other workload and starting RR about six weeks earlier than in 1998. This has meant a reduction in the number of hours the students spend on the course. For IRM in 1999 the students were expected to put in around 220 hours of work (120 hours in 3 intensive 40-hour weeks and 100 hours spread over 12 weeks) compared to 262 hours in 1998.

6.4 Student Feedback

One or two of the students in the class felt that there were too many similar tasks required of them in IRM—they saw comparing two papers as the same thing as doing a literature review of five or six papers—and felt the course could have been shorter. These same students did, however, after the completion of RR, say that IRM was a valuable learning exercise and felt that we should definitely continue offering it.

In general the students seemed to see the importance of IRM once they had embarked on their research. In fact, some of the 1998 students reported at the end of the year that they had felt quite comfortable doing their research as they had an idea of the process and felt that the research would have been much harder to do without IRM.

6.5 Further Evaluation

RR ends in late October and we intend to survey the class as to their perceptions of how IRM affected their progress in RR. The results of this will be reported at SAICSIT '99 and can be found in [3].

7 Conclusion

Our current view is that IRM has been a success. This is a not a view taken lightly—our Honours programme is very intensive and so we have to choose carefully what we put in and what we take out. We still see RR as being the most important research component of the Honours programme, but IRM has shown that it can play a valuable supporting role. In summary, the advantages of the course are:

- it gives students insight into the nature and methods of research
- it prepares students better for the research report that they must conduct

- we can introduce many research-related concepts, that would otherwise only be learned by trial-and-error or through considerable effort from the supervisor
- it gives a student a broader background into research methods in computer science (i.e. they are exposed not only to the research method they use for their research, but other approaches that would be suitable for different types of problems).

In 1999 we have made some modifications to timing, content and presentation and will reassess the course at the end of the year. We are still struggling with some issues, mainly related to resources available: what material to cover and how to cover it; workload for staff and students etc. A related issue is involving more staff in the running of the course. We expect that it will take a year or two more before the course is fully developed but we believe it has already made a difference to our students' understanding of research.

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Received: , Accepted: