Introducing a group research project into a second-level mathematics course

Susan Worsley, **Anthony Bracken**, **Katrina Hibberd** and **Phillip Isaac**, School of Mathematics and Physics, The University of Queensland, Australia
sue.worsley@maths.uq.edu.au; ajb@maths.uq.edu.au; keh@maths.uq.edu.au; psi@maths.uq.edu.au

Abstract: *In 2008 The University of Queensland introduced a revised Bachelor of Science degree that required a stronger emphasis on research studies. In order to give students a taste of mathematics research, a group research project was introduced into a second level mathematics course. The inclusion of a group research project also strengthened the second year mathematics program by addressing some of the desired graduate attributes relating to in-depth knowledge and communication skills. Previously, there had been little opportunity for students to research, review and critique an article or give a seminar presentation in a mathematics course. This project aimed to address these issues as well as to promote and encourage students' interest in mathematics.*

The chosen second level course on applied mathematical analysis usually has enrolments of 70-90 students and most students with an interest in mathematics take this course. The students were required to form groups, investigate a topic chosen from a list, give a group presentation and write a report in the form of a short journal article. The topics were chosen to demonstrate the interdisciplinary nature of mathematics and encouraged students to find and investigate other papers related to their topic.

In this paper we cover the development and implementation of the project. We also present the results of the questionnaire collected on completion of the project together with some reflections of those involved in the project. The discussion evaluates the success of the group project at achieving its objectives and suggests future improvements.

Introduction

The University of Queensland introduced a revised Bachelor of Science degree (BSc) which became effective from January 1, 2008. Part of this restructure recommended a strong element of research as stated in a prior review document (The University of Queensland, 2006; p.19) "That an optional structured research apprenticeship experience ('Science in Action') be developed across years 1 to 3 of the BSc"

In line with this recommendation a third year capstone course is being introduced in the mathematics major that will take effect from 2010. This course will be designed to give students research experience as well as to develop their written and oral presentation skills. The capstone course will be more beneficial to students if they have already developed some of the research, writing and presentation skills required. It was also evident from the goals stated in a Mathematics Majors document (University of Queensland, 2007) that the mathematics program in second year required strengthening in terms of the development of some of the graduate attributes relating to in-depth knowledge and communication skills. In the past, there was little opportunity in the mathematics coursework offered to second level students to research and review an article or to give a seminar presentation.

One of the challenges of a second year course is to strengthen students' enthusiasm for mathematics and to demonstrate how it can be applied to other disciplines. A mathematical modelling course provides the ideal framework for this by showing students the inter-disciplinary nature of mathematics as well as teaching them other skills such as creative problem solving and analysis (Fry, Kettridge & Marshall, 1999). Such a course also offers an excellent context for working in groups (Berry & Nyman, 2002). It was decided to maximise the desired outcomes by including a group research project component in a second level modelling course, having in mind also that working in groups can be beneficial to students in terms of cognitive learning and on a social level (D'Souza & Wood, 2003). Group learning also has a positive effect on student achievement and attitude to study as well as reducing attrition rates (Cooper & Robinson, 1998). For example, at the University of Northern Colorado in an abstract algebra class run partly in small groups for the first time, students indicated that they enjoyed the subject more than previous students, and felt that they had learned a lot from each other (Grassl & Mingus, 2007).

Introducing a group project has many associated organisational difficulties such as sorting students into groups, designing assessments and coordinating the implementation of the project (Feichtner & Davis, 1984). Much had been learnt from a previous group project that had already been introduced into a large first year course (Worsley, Hibberd & Maenhaut, 2007). In addition to the main aims of that previous group project, of building collaborative skills amongst students and demonstrating the relevance of mathematics, we also aimed to develop students' research skills.

The Applied Mathematical Analysis course MATH2100 has been offered for several years at The University of Queensland, in the second semester of each year. It caters for 70-90 students. Most students who are interested in mathematics take this course as part of their second level studies. The course covers topics ranging from systems of ordinary differential equations and Laplace transforms to partial differential equations and Fourier series, with some emphasis on applications. Students normally attend three lectures and one tutorial per week and are assessed on ten assignments and one final exam. The group research project was introduced into this course primarily to allow students to develop and extend their research skills, in preparation for the third year capstone course. Other benefits for the students were to develop communication, management and teamwork skills. It was also intended to promote and encourage students' interest in mathematics by showing how mathematics can model real world phenomena ranging from economics, to faults in the transmission of nerve signals in the brain. In groups of three or four, students chose a topic from a list, found other papers relating to the topic, gave a group presentation and collaborated on a written paper.

Implementation

Organisation

The group research project was run over ten weeks starting in the first week of the thirteen week course, when students were offered information skills workshops at the library. Here they were shown how to access and use library tools such as database searching (*MathSciNet*, *Web of Science*), and they learnt about citation styles and avoiding plagiarism. They were also shown how to evaluate the quality of resources they found. In the second week students formed their project teams within their larger tutorial groups. This ensured that they could have regular contact with other group members and also allowed the presentations to be held in the normal tutorial time slots.

By the fourth week each group had to submit a progress sheet indicating that they had created a team, chosen a topic and formulated a plan on how to divide the work between group members. The progress sheet was included to encourage students to start on their projects early and think about how they would organise the work between members. The five minute presentations were held in week seven with each group peer-reviewing one other group's presentation. In week ten each group submitted a written report in the form of a short journal article, with a statement made by each member outlining their contribution to the project. The statements had to be signed by all team members certifying their agreement with the stated contributions. The statement of contribution was introduced to try and reduce the possibility of a student doing little work in a group and benefiting unfairly from the efforts of more productive members.

Two additional tutorials outside normal tutorial times were provided to give student specific project support. In the first tutorial the students were shown how to give an effective presentation. In the second they were shown a presentation on mathematical writing and preparing a written report.

Time was also made available in these presentations to give students an opportunity to ask questions they had about their projects.

In addition to these support tutorials, a discussion board was set up on *Blackboard* (an e-learning tool) enabling students to email each other about any project problems. *Blackboard* was also used to make regular announcements and reminders as well as to supply students with detailed instructions on all the project requirements. Students were encouraged to email the course coordinator with any questions or problems they had about the project.

Topic Choices

To enable students to start work on the group research project early, topics were developed on systems of ordinary differential equations which are covered by lectures in the first part of the course. The topics were designed to demonstrate the interdisciplinary nature of mathematics.

The students were able to choose from a list of five topics. Each topic description referred students to a journal article which they had to locate and use to find others relating to the topic. They were required to formulate a hypothesis, evaluate a system of linear or nonlinear differential equations, find their critical points, consider other possibly more relevant systems, suggest improvements and visualise future applications. The titles of the five topics were:

1. *Radioactive Fruit Trees*: This considers the long-term presence of radio caesium in fruit trees in Northern Greece as a result of the Chernobyl incident.
2. *Lead in the Human Body*: A compartment model is used to look at the transfer of lead between the bones, blood and tissue.
3. *Neural Networks*: Neural networks using Van der Pol equations are investigated and analysed to explain the effects of damping in these equations.
4. *Economic Growth*: The Solow model is used to model the production of a country's economy.
5. *Fishing*: This uses the Lotka-Volterra model to interpret data collected between 1914 and 1923 that showed changes in the mix of fish caught during this period.

Each project was carefully designed to enable the topics to be worked on in groups. All projects were chosen by at least one group. It is hoped to develop more projects in future years.

Assessment process

The project was run in the first half of the course and was worth 15% of the final mark, based on the quality of the final written report. The progress sheet, presentation and participation in the peer-review process were all compulsory components of the assessment but did not count towards the final mark. To accommodate the project, the contribution of the final exam was reduced from 65% to 50% of the final mark, with ten assignments contributing 35% as in previous years. The form of the final exam was modified so that students would receive less assessment in the areas of mathematics covered in the projects. The five components of the assessment were:

Progress sheet

The progress sheet, as well as addressing workload organisations within the group would also confirm that a topic had been chosen and a work plan formulated. Students were required to submit the form by the fourth week of semester.

Presentation

In the seventh week of semester each group was required to give a five minute presentation of their project in their normal tutorial time. Students were given the option to choose one member to present, or to involve the whole group. Attendance was compulsory for all members of the group.

Peer Assessment

Each group was required to assess one other group's presentation. The peer assessment enabled each group to receive some feedback which would assist them in completing the final report, and also made students more aware of the challenges in preparing a good presentation. Students were supplied with assessment sheets to assist them in the process.

Written report

Each group member of a group received the same mark (out of 15), based on the quality of the final report submitted by the group. They were required to prepare a short collaborative journal type article describing the formulation and analysis of the model they had chosen to investigate. The results they obtained needed also to be interpreted. The final report was restricted to ten pages.

A simplified assessment process was developed to aid marking by the tutors. The tutors and students were given an assessment criteria matrix listing five areas of assessment: referencing, language, content, mathematics and interpretation of results. These were subsequently divided into four levels representing marks 0 to 3. In each level was a detailed description of explicitly what was required to achieve that mark. The tutors circled the appropriate level of achievement in each area.

Declaration of contribution

The students were required to submit a short statement by each group member outlining their contribution to the project with their written report. All team members had to confirm the statements.

Tutors

Tutors were required to arrange students into groups, organise the presentations and peer assessments, and mark the final projects. They were not required to answer questions on the topics. Two tutor meetings were held with the authors to discuss the running of the project, answer questions and generally provide support. The tutors were also given written instructions outlining their role in the project and on the marking process. The tutors were sent regular emails to update them on any issues and remind them of the various deadlines.

Outcomes

Assessing the effectiveness of the project comes from the observations made by all those involved in the project, from the student feedback and from other data collected.

From the observations made by the librarian who conducted the opening workshops, the 34 students who attended were keen to participate. Some did not know what a database was while others were unaware of *Web of Science*. They were shown strategies for searching and made aware of the services and facilities available at the library. The librarian felt that in future workshops, students could be given more hands-on searching tasks to complete.

The 74 students enrolled in the course formed 22 teams of three or four. There were a few problems with the formation of groups at the start. One group opted to stay as a two-person group after one member of their group withdrew from the course. At the end of semester, members of another group commented that 'one of our members did nothing at all', which required detailed discussion to resolve. Most other groups worked admirably together. Very few questions were asked in the two special support tutorials provided. We felt that maybe the additional tutorials were held before many of the groups had begun working on their project despite being encouraged to spread the workload over the first ten weeks of the course.

The presentations which occurred during normal tutorial times went smoothly with many enthusiastic and inventive talks as well as vibrant discussions. Most were prepared on PowerPoint slides. Students were able to incorporate what they had learnt from their presentation in their final report.

Results

The student survey

At the end of the course 39 of the students voluntarily completed a survey regarding the group research project. The survey consisted of 21 multiple choice questions using Likert-style responses (1=strongly agree, 2=agree, 3=neutral, 4=disagree, 5=strongly disagree) and one open ended question asking for any comments. The questions concerning the key results are shown in Table 1.

	Question	**1**	**2**	**3**	**4**	**5**
Q3	I have gained knowledge on how mathematics can be applied to solve practical problems.	7	23	5	3	1
Q6	I was given enough time to work on the project	10	25	3	0	1
Q7	I had sufficient research resources to complete the project	7	23	5	3	1
Q8	It was difficult to split the work needed to be completed between group members	12	13	5	8	1
Q19	The group project has improved my skills in mathematical writing	4	12	14	8	1
Q20	The group project has improved my research skills	3	13	15	7	1
Q21	The group project has improved my written and oral presentation skills	2	6	12	17	2

Table 1: Some key results of student survey shown by question and responses.

We analysed the results from the student survey using confidence intervals for the mean responses and p-values against the neutral value of 3.

Several statistically significant results indicated that students had gained knowledge on how mathematics can be applied to solve practical problems (Q3) ($CI_{.95}$ = 1.90-2.46, $p < .01$), felt that they had sufficient research resources to complete the project (Q7) ($CI_{.95}$ = 1.90-2.46, $p < .01$) and found it difficult to split the workload between group members (Q8) ($CI_{.95}$ = 1.95-2.69, $p < .01$). It was also felt that they had been given enough time to complete the project (Q6) ($CI_{.95}$ = 1.69-2.15, $p<.01$).

Three questions (Q19, Q20 and Q21) invited students to respond to statements on gaining research skills to do with mathematical writing, general research, and written and oral presentation. In all three cases, the distribution of responses was not found to be statistically significant (Q19: $CI_{.95}$ = 2.44-3.05 ns, Q20:$CI_{.95}$ = 2.46-3.03 ns, Q21: $CI_{.95}$ = 2.97-3.56 ns).

In the open ended question eight students commented on marking with most of these indicating that there should be marks allocated to the compulsory components. Thirteen students commented on group dynamics with the majority of these concerned with one member not contributing fairly to the workload. Three students requested more structure and out of the twelve general comments about the project nine students found the project positive, beneficial, enjoyable, relevant and even fun.

Marks on submitted reports

Based on the assessment criteria matrix as outlined above (under the Written report section), there were high levels of achievement in the final report with a mean mark of 12.41 (SD = 2 .24) out of 15. There was little variation between the various components (each worth 3 marks) of the report with referencing getting the lowest mark with a mean of 2.32 (SD = 0.78) and language the highest with a mean of 2.59 (SD = 0.67).

Discussion and conclusion

The challenges of introducing this group research project were met by designing clear instructions, organising tutor involvement and communicating with students. The survey showed that students had adequate choices of topics and plenty of time to complete the project.

Some of the main aims in introducing a group research project into the Applied Mathematical Analysis course were to introduce and develop students' research, teamwork and presentation skills to a level required for the third year capstone course. From the outcomes of the group research project we believe that the students finished the semester with many of the skills required to enter the capstone course. Another aim was to demonstrate to students the relevance that mathematics has to solving applied problems, as strongly indicated by the survey results.

Responses from student surveys were not unanimously supportive of the notion that the project developed their research skills. There is, however, some anecdotal evidence that some students had in fact developed these skills as a result of the group research project. Observations made by the librarian at the beginning of the semester and the standard of submitted reports are two such indications. With regard to collaborative skills most groups worked reasonably well together with the exception of the one group mentioned previously. Our assessment scheme confirmed, as previously suggested by Cooper and Robinson (1998), that giving all members the same mark can cause problems. A possible way to avoid this situation is to make student participation more significant in the peer assessment component of the project (Feichtner & Davis, 1984). This is being considered for future years. Further discussion on other aspects of the project is deferred to a future publication.

One of the important aims was to show the relevance of mathematics and how it can be applied to other disciplines. The survey results and students' comments indicate that this was well met and was reinforced by the many comments we received when talking to students during the presentations.

Overall we believe that the exercise was worthwhile and should be continued in future years. There are certainly challenges facing the successful introduction of research components into the undergraduate mathematics curriculum, but it seems clear that this will be expected more and more in the future, and we believe that a second-level group research project along the lines of the one described can be one important component in this process.

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The authors advise that Human Ethics clearance was not sought for this research.