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Student Perceptions of a Day-Long Mathematical Modelling Group Project

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BACKGROUND
One of the key learning aims of our first year mathematical modelling course is to teach students the mathematical modelling process, including how to apply the process to solve non-trivial problems. A significant barrier to accomplishing this task is that time constraints have meant in-class examples and traditional assessment tasks have been oriented towards small scale problems. To allow students to grapple with a larger scale problem, while not taking up a large amount of time, a day-long group project on modelling was incorporated into the summer school offering of our mathematical modelling course. The project required students to work together in teams of four over an eight hour period, to produce a written report that answered an open ended question. A longitudinal survey was used to track student perceptions both pre and post the day-long group mathematical modelling project.

PURPOSE
The main purpose of this study was to determine if taking part in a day-long group project was an experience that students valued and one that they perceived as helping increase their understanding of the mathematical modelling process. In particular the project investigated student perceptions of this form of assessment both before and after the experience, to track how their perceptions changed.

DESIGN/METHOD
Feedback was captured via short anonymous questionnaires, using questions on a Likert scale and a selection of open ended questions. Questionnaires were presented at three points during the course: the first week of class, the day following the project day and at the conclusion of the course.
The data were analysed to see what students thought of the day-long group project and how those perceptions quantitatively changed over time, particularly with regard to whether or not they found the project a valuable learning experience and whether or not it increased their understanding of the mathematical modelling process.

RESULTS
By the end of the course the majority of students agreed that taking part in the day-long group project was a valuable learning experience that improved their understanding of mathematical modelling. Some students changed their opinion over the duration of the course. In general, students were most positive about the project at the start of the course and least positive just after the project day. Although fewer than half of the students were happy with the quality of their work, the majority enjoyed working as part of a team and most students were happy with the mark their group obtained. Despite these positive outcomes, fewer than half of the students were keen to do similar assessments in the future.

CONCLUSIONS
Student perceptions on how a day-long group project would aid their understanding generally changed over time, with a common observed pattern being a very positive initial outlook that then dropped before rising again by the end of the course. Students performed very well in the project, with each group demonstrating excellent mathematical modelling skills, yet individuals were generally unhappy with the quality of the work they submitted. This demonstrated a gap between their perceived performance and their actual performance. Students were more concerned with answering the question posed, rather than with applying the mathematical modelling process and demonstrating an understanding of that process.

KEYWORDS
Day-long group project.

Introduction

All first year engineering students at the University of Auckland are required to take *Mathematical Modelling 1*. One of the key learning aims of this course is to teach students the iterative mathematical modelling process, including how to apply the process to solve non-trivial problems. A significant barrier to accomplishing this aim is that both in-class examples and traditional assessment tasks have been oriented towards modelling on a small scale. This situation is due to the inherent limitation of the kinds of problems that can be presented succinctly in a lecture or attempted by students in tests, exam questions and weekly assignments.

If students are to learn how to solve non-trivial problems it is useful for them to engage with at least one large mathematical modelling problem, in order to learn how to apply the skills they have developed while solving smaller problems on a larger scale. In the past the teaching team have attempted to accomplish this by setting individual project work. However marking individual project work can be an expensive undertaking that requires a significant investment of time, often by a large team of markers. When the marking load is spread it is also much harder to ensure consistency of marking. Traditional individual projects were eventually discontinued due to a number of significant flaws. One major flaw was that students had to be directed down the same solution path, when working through the problem, in order to enable consistent marking. This left little room for creativity or exploration (both skills that should be encouraged). Another flaw was that many students worked together or copied from each other, so their mark was not a true reflection of their individual ability.

The inclusion of project work presented further issues in the summer school offering of our mathematical modelling course. The standard offering runs over a full semester, which includes twelve teaching weeks, broken in half by a fortnight long mid-semester break. In summer school the entire course is delivered in just six unbroken weeks. This makes it very difficult for students to find the time to tackle large-scale projects.

According to Capraro and Slough (2009), project based-learning can be defined as “an ill-defined task with a well-defined outcome”. For the 2012 summer school offering the author decided to trial a project-based learning approach, getting students to tackle a large-scale problem, in the form of a day-long group project. An open ended problem was presented at the start of the day and teams of four students were required to submit a written report eight hours later. The desired learning outcome was an increase in students’ understanding of the mathematical modelling process, via its application.

The rationale for trialling this new day-long group project approach was as follows:

- By working in groups, students were encouraged to collaborate and work together, skills that they will need in the work-place. It also gave them the opportunity to accomplish more than a single student might, over a short time span, while enabling them to help each other learn.
- By requiring the project to be completed in a single day, it could be fitted into the tight summer school time-scale, while also giving students practice on working to produce an answer under pressure, as is often necessary in industry.
- By using groups of four, as opposed to individual work, the marking load was quartered, meaning it was just possible for the teacher to mark all projects, ensuring marking consistency while allowing students free reign to use whatever methods they liked.
- Students were required to produce a written report which used their information literacy skills, so the project emphasized the importance of those skills and gave them an opportunity to practice them.

As the day-long group project concept had not been used before, the author was interested in running a pilot study to investigate whether or not students found taking part in the project an effective learning tool. Of particular importance was to what extent students felt the day-long project helped increase their understanding of the mathematical modelling process, as this was the main learning outcome related to the introduction of the project to the course.

Group work was not previously a feature of this course, so careful thought was put into group size and member selection. Davis (1993) suggests that in general, groups of four or five members work best for project based group work. Borri and Maffioli (2007) give the ideal group size for project based learning as between three to six students. A group size of four was chosen, based in part on the quality of output produced by groups of this size on similar open ended problems (posed during day-long problem solving competitions run by the author). Groups of four also ensured that if a student pulled out on the day, due to illness, the group would not reduce to a pair.

Group allocation methods can be divided into two categories; teacher-selected or self-selected. While both approaches have strengths and weaknesses, in this case it was felt that it was important for groups to be assigned by the teacher, to ensure a balanced distribution of basic mathematical ability. For engineering design projects (which utilise a similar skill set) it has been shown that groups that are heterogeneous with respect to academic ability generally perform better (e.g. Brickell, Porter, Reynolds and Cosgrove, 1994). Due to the very diverse abilities of the cohort, it was highly likely that self-assignment by students would produce very unbalanced groups, reducing the effectiveness of the learning experience. To create heterogeneous groups, with respect to mathematical ability, the class was first divided into quartiles based on student performance in a foundational mathematics skills test. Groups were then formed by randomly selecting one student from each quartile.

Yetkiner and Capraro (2009) state that "the construction of the ill-defined task is very important and requires careful consideration of standards, learning objectives, resources, time and student characteristics." Careful thought was given to constructing a question that was both open ended and possible to answer given their current skillset. The question used was:

> *In the Disney Pixar movie "Up", 78 year old Carl Fredricksen attaches a large number of balloons to his house and flies it away.*
>
> *How far would a house lifted by balloons travel before landing?*

In keeping with the concept of an "ill-defined problem", the phrasing was purposely open to interpretation. For example no definition of the word 'far' was given nor were any details provided regarding the weight of the house or the number and type of balloons used. This was done in order to require groups to make appropriate assumptions and provided an opportunity for them to examine the effects of their assumptions, key parts of the modelling process.

Each group submitted a single report for their entire group, with the default position being that all members of the group received the same mark. Awarding the same mark to every group member was logistically simpler than tracking individual contributions and also mirrored the reality of the work place, where the performance of the group as a whole is often what is judged. The author felt that some checks were needed to reduce the chances of group members free-riding, where "an individual collects the benefits of group output without contributing" (Strong and Anderson, 1990).

Peer review has been shown to be very effective in virtually eliminating issues related to free-riding (Dyrud, 2001). On the day following the project, students assessed both the effort and contribution of each team member. Only the marker saw these self and peer assessments, so they were able to comment freely on their fellow group members. Students were aware that if this process revealed a significant workload imbalance, further investigation would occur. This would take the form of the marker discussing the situation with the group members and then assigning individual marks based on individual contributions, using a divided mark approach, which students perceive as “a fair way of arriving at grades for group work” (Maiden and Perry 2011).

Methodology

This study investigated the perceptions of students enrolled in the 2012 summer school offering of Mathematical Modelling 1, captured by three surveys. A total of 54 students were enrolled in the class which comprised a very diverse cohort, both in terms of background and ability. For many students this was their first university course, while many others had already completed a year of study. A small number of students had two or more years of tertiary experience. Some students were extremely academically able, taking the course in order to ‘fast track’ through the four-year engineering degree programme in just three years. Other students were much less able, lacking the necessary background knowledge and/or repeating the course as they had failed on their first attempt.

In order to obtain ethics approval for this study, participation was both anonymous and voluntary. To ensure the anonymity of participants, all surveys were distributed, collected and transcribed by people unrelated to this discipline. To allow for comparison of individuals across the surveys, students identified themselves using a unique code of their choice.

Feedback was collected via three short paper-based self-report questionnaires, each requiring under ten minutes to complete. Surveys were distributed in class, which limited participation to those present. Typically around 40 students attended each lecture and the majority of students chose to participate. Unfortunately, some students were either absent on one or more surveyed days, or failed to use the same identification code on each of the three surveys. This resulted in full longitudinal data sets across all three surveys for a total of 27 students. For the sake of simplicity and to allow comparisons over time all quoted figures relate to this sample of 27 students who completed all three surveys.

Survey one was distributed at the end of the first week of class, after students had received both a verbal and written introduction to the day-long project concept. Students were then assigned to groups and did some team-building exercises in the middle of the third week. They completed the project in the middle of the fourth week and survey two was distributed the following morning. Survey three was distributed at the *end* of the sixth week, after students had completed all internal course work and received their project marks.

Each survey consisted of seven to nine questions to be answered on a standard five point Likert scale (1 = strongly disagree, 2 = disagree, 3= neutral, 4=agree, 5= strongly agree). A response of four or five to a statement corresponded to a positive viewpoint. Four open-ended questions were also included at the end of each survey, allowing for free-form comments.

To investigate the fundamental question of whether or not students perceived taking part to have been a valuable learning experience, both survey two and three sought feedback on the statement:

> *Taking part in the day-long group project was a valuable learning experience*

To investigate student perception on whether or not taking part in the project helped increase their understanding of the modelling process the author asked students to rank their agreement with the following statement in survey one:

> *I think that doing this project will help increase my understanding of the mathematical modelling process*

There was a related follow-up question asked in both survey two and three:

> *The project helped increase my understanding of the mathematical modelling process*

Survey one and two included questions that addressed group creation and to what extent students enjoyed working as part of a team. Survey one asked students to rank their agreement with the statements:

I am happy with how the team members will be assigned

I am looking forward to working as part of a team

Survey two followed up with:

I was happy with how the teams were assigned

I liked working as part of a team

Survey two also included further questions around the theme of teamwork:

I felt my team worked well together

I was happy with the quality of the work my team submitted

I preferred working as part of a team to working as an individual

With regards to the form of the assessment, students were asked to comment on the following statement in survey one:

I am comfortable with the idea of this form of assessment

Surveys two and three then asked them to comment on the related statement:

I would like to do similar assessments in future courses

As students are very focused on their performance in assessments, the final survey also asked them to comment on the statement:

I was happy with my mark for the project

Results

The key thing the author wished to determine was whether or not taking part in the day-long group project was a valuable learning experience. Of particular interest was student perception on whether or not it helped increase their understanding of the mathematical modelling process.

With regards to the day-long group project being a valuable learning experience, 63% of respondents in the second survey affirmed that taking part in the project was valuable. This figure rose to 74% by the third survey. A summary of the Likert responses for both surveys are shown in Figure 1.

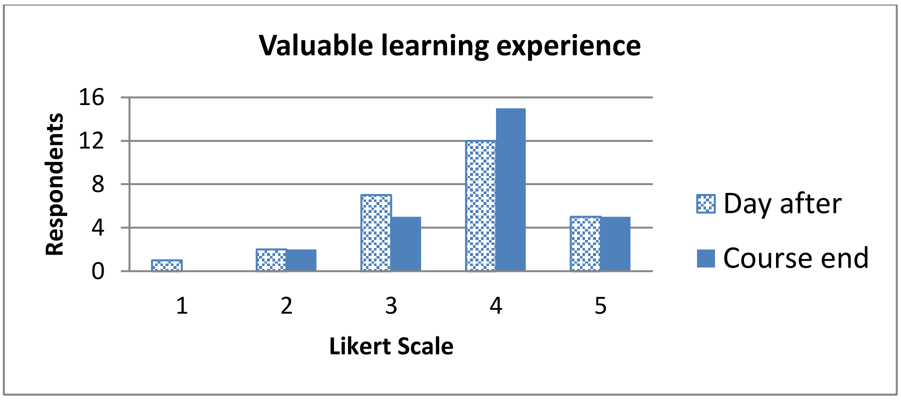

Figure 1: Student opinions regarding whether the project was a valuable learning experience (27 students). 4 and 5 equate to a positive response.

The majority of students maintained the same opinion about the value of the learning experience across both surveys two and three. Some students however changed their opinion. This is interesting as the only experience in the intervening time that directly related to the project was the return of marks. In between the surveys they also attended lectures and tutorials plus sat the terms test and engaged with assignments, which may have contributed to the change in perspective. All observed patterns in opinion between the two surveys are summarised in Table 1.

Table 1: Opinion patterns regarding whether the project was a valuable learning experience

Pattern	Interpretation	Percentage of students
—	Opinion remains constant	59
/	Opinion rises	26
\	Opinion drops	15

To investigate student perceptions of how the project influenced their understanding of the modelling process, the first survey asked them to consider to what extent they thought that doing the project would increase their understanding while the second and third followed up asking if it had actually helped increase their understanding. The results are summarised in Figure 2.

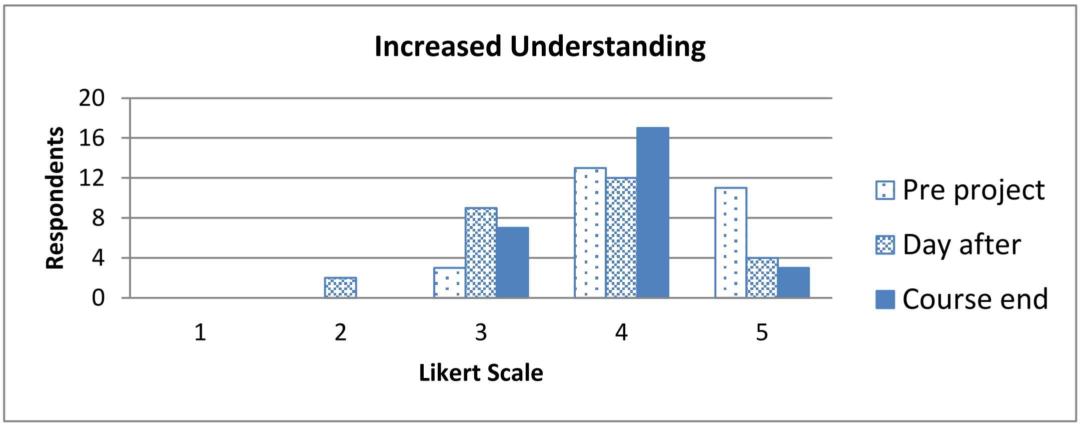

Figure 2: Student opinions regarding whether the project increased student understanding of the modelling process (27 students). 4 and 5 equate to a positive response

The majority of students had an initially positive outlook, with a total of 89% of students believing that doing the project would help increase their understanding of the modelling process. On the day following the completion of the project, the proportion of positive responses had dropped significantly, down to 59%. After completing the remainder of the course (and receiving their marked projects back) the proportion of positive responses rose up to 74%.

A number of response patterns by individuals were observed in the data, with the three most common patterns summarised in Table 2. A further five patterns were observed, with each of the remaining instances having only one or two students.

Table 2: Common opinion patterns regarding whether the project increased student understanding of the modelling process.

Pattern	Interpretation	Percentage of students
	Opinion drops, then rises again	33
	Opinion remains constant	26
	Opinion drops then stays low	15

The majority of respondents (52%) recorded a drop in their opinion from survey one to survey two, showing that their initial high expectations had not been met, although perhaps whether or not they actually enjoyed engaging with the project question and working in groups was a convoluting factor.

Students were informed from the outset that groups would be created by random assignment, while using a method that would also ensure balanced ability groups. In the first survey 74% of students affirmed that they were happy with how team members were to be assigned. Following the project day, the percentage of positive responses from the tracked students remained at 74%. The majority of students maintained their initial positive opinion across both surveys. Four students, however, switched to a positive opinion and four students switched from a positive opinion to a neutral one.

74% of students also indicated that they were looking forward to working as part of a team and the positive responses increased slightly on the second survey (due to a net increase of one student) with 78% affirming that they liked working as part of a team.

The second survey included several further questions on the experience of working in teams. 67% of the tracked sample felt their team worked well together, while 67% also said they preferred working as part of a team to working as an individual. Only 37% were happy with the quality of the work their team submitted, yet 89% of the students tracked across all surveys indicated that they were happy with their project mark (the three remaining students expressed a neutral opinion on this issue).

Although 89% of tracked students indicated they were comfortable with the idea of this form of assessment, support for doing similar assessments in the future was not high. On the day following the project just 33% indicated that they would like to do similar assessments in the future. By the end of the course this figure had risen to 48%.

Discussion

In general, students were very positive about the project at the start of the course. Initially almost all of them agreed or strongly agreed that the day-long project would help improve their understanding of the mathematical modelling process. This positive viewpoint may well have been helped by the significant amount of time we spent in class discussing the project, emphasizing its learning objectives and explaining the rationale behind it. As this was a new initiative a considerable amount of effort was put into making it work.

It is perhaps unsurprising that many students lowered their opinions on the project by the second survey. Their initial expectations were relatively high, so it was likely that any movement would be downwards. By the time they completed the second survey they had just experienced the reality of having to grapple with a problem under pressure for eight hours, a somewhat exhausting task. The number one concern mentioned in the first survey was not having enough time to complete the project. While every team succeeded in completing the project on time (or just past with a small late penalty), several people made comments such as they “could've achieved more if more time was given”, indicating that time was a significant constraint. Some students suggested the project be run over a longer period but others liked that it was over and done with in a day, so on balance the duration is probably about right.

Based on informal discussions with students on project day, the problem posed apparently appealed to the students however my results indicated that they found it hard to work on such a “vague” problem. Several students gave feedback that they wanted “a more confined question, rather than [it] being too open ended.” This was not unexpected, given the current state of secondary education in New Zealand, where mathematics students are usually working towards what is perceived as the one right answer. Although quite a few students expressed a desire for a question that was “not so vague”, many people were keen on the “real-life” nature of the problem. The students who desired a more prescribed problem seemed to have missed the point that one reason for an ill-defined problem was so that they could practice making appropriate assumptions. It is good to be aware that students did not understand this, as this point can be emphasized in the future.

The majority of students enjoyed working as part of a team and there were many positive comments about the group nature of the project. Their opinion of the project and its effectiveness for increasing their mathematical modelling understanding had risen by the third survey, as had the number of students who would like to do similar assessments in the future. This may have been related to the release of their marks, which based on feedback from informal discussions, were by and large better than students had anticipated.

Given that the students performed well and generally enjoyed worked in groups it was a little disheartening that fewer than half of the students expressed an interest in doing similar day-long group projects in the future. This begs the question, what do they dislike about this form of assessment? As their opinions on working in teams were generally positive, it is perhaps more related to the length of the project, the nature of the question and/or group assessment. Future survey questions could be based around determining why students do not favour this form of assessment highly.

The quality of submitted reports was generally excellent and from an assessor’s viewpoint, the groups had risen admirably to the task. It is hard to quantify exactly how effective the project was in increasing student understanding but it was pleasing to note that this was the first offering of the summer school course where every single student passed (by contrast each of the previous four offerings had five or more students fail).

Due to time constraints the group assignment was done purely based on mathematical ability. It did not account for factors such as gender or ethnicity. Unfortunately if the dynamics of gender and race are ignored or misunderstood, group work may actually inhibit or detract from learning (Rosser, 1998). While learning to work with people from varying backgrounds is an important skill, it was not the main learning objective of the project. Accounting for gender, race and background in the group assignment process may well be desirable for any future day-long group projects of this nature, to ensure minorities are not disadvantaged.

A common initial concern was that other group members would not pull their own weight (i.e. there would be free riders). Although surprisingly few problems were mentioned in the self and peer assessments of the groups, it was evident from the assessments that people felt some group members had worked harder than others. In the future it may be worth implementing a divided mark approach (that was reserved as a stop-gap measure), rather than assigning every group member the same mark.

Conclusion

Student perceptions on how a day-long group project would aid their understanding generally changed over time, with a common observed pattern being a very positive initial outlook that then dropped before rising again by the end of the course. This indicated that experiences following the project had an impact on their perception of its value.

Students performed very well in the project, with each group demonstrating excellent mathematical modelling skills, yet individuals were generally unhappy with the quality of the work they submitted. This demonstrated a gap between their perceived performance and their actual performance. Students were more concerned with answering the question posed, rather than demonstrating how they had applied the mathematical modelling process. Providing a clear rubric on how the project was to be marked did not appear to be enough to counter the tendency of students to focus on the answer to a problem rather than the learning objectives.

It should be emphasized that this pilot study addressed student perceptions only. It was observed that perceptions can and do change over time. Given that there was a disconnect between the understanding demonstrated by students and the perceived quality of their submitted work, it is important to consider whether or not students are able to effectively evaluate if a project has helped "increase their understanding of the mathematical modelling process". It is entirely possible the students may underestimate or overestimate the value of a given assessment. Future research should consider how to evaluate and measure student "understanding of the mathematical modelling process", independently of student perceptions. It would be worthwhile investigating whether their perceptions matched reality.

References

Borri, C., & Maffioli, F. (Eds.). (2007). *Re-engineering Engineering Education in Europe*. Firenze. Firenze University Press.

Brickell, J. L., Porter, D.B., Reynolds, M. F., & Cosgrove, R.D. (1994). Assigning Students to Groups for Engineering Design Projects: A Comparison of Five Methods *Journal of Engineering Education,* July 1994.

Capraro R. M & Slough, S. W. (Eds.). (2009). *Project-Based learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach*. Sense Publishers.

Davis, B. D. (1993) Collaborative learning: Group work and Study teams. In *Tools for teaching*. San Francisco: Jossey-Bass.

Dyrud, M.A. (2001). Group projects and peer review. *Business Communications Quarterly* 64, no. 4: 106–12.

Maiden, B., & Perry, B. (2011). Dealing with free-riders in assessed group work: results from a study at a UK university. *Assessment & Evaluation in Higher Education*, *36*: 4, 451 — 464.

Rosser, S.V. (1998): Group Work in Science, Engineering and Mathematics: Consequences of ignoring Gender and Race. *College Teaching*, 46:3, 82-88

Strong, J., & Anderson, R. E. (1990). Free Riding in Group Projects: Control Mechanisms and Preliminary Data. *Journal of Marketing Education, 12*: 61

Yetkiner, Z. E. & Capraro R. M. (2009). Factors influencing the implementation of STEM Project-Based learning. In Capraro R. M & Slough, S. W. (Eds.), *Project-Based learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach*. Sense Publishers.

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