STUDENT RESPONSES TO TEAM-BASED LEARNING IN TERTIARY MATHEMATICS COURSES.

Judy Paterson[1], Louise Sheryn[2] & Jamie Sneddon[1]
Department of Mathematics, Auckland University[1]
School of Education, Auckland University[2]

Abstract

Starting in 2009 we have implemented a Team Based Learning (TBL) model of delivery in two mathematics courses and one mathematics education course involving a total of 295 students. Qualitative data from evaluations, observations and interviews is used to begin to answer four questions raised by the Seldens (2001) regarding teaching mathematics at tertiary levels. Our analysis indicates that students say that TBL creates an environment in which they are active, have productive arguments and discussions and benefit from immediate feedback. There is scant evidence of any group being disadvantaged by this model of delivery.

Key words
Team-based Learning, Tertiary Mathematics Teaching, Group Work

Introduction
In their 1999 report, “Tertiary Mathematics Education Research and its Future,” later included in an ICMI study, the Seldens raised important questions about co-operative learning: "How might one change the classroom culture so students came to view mathematics, not as passively received knowledge, but as actively constructed knowledge? What are the effects of various cooperative learning strategies on student learning? What kinds of interactions are most productive? Are some students advantaged while others are disadvantaged by the introduction of cooperative learning?"(Selden & Selden, 2001, p. 207). In this paper we will use students’ responses to the introduction of a mode of delivery called Team-Based Learning (TBL) into two mathematics courses and a mathematics education course at Auckland University, New Zealand to begin to answer these questions.

Team-Based Learning is a particular cooperative learning strategy. It is widely used in the health sciences and medical education (Haidet, O’Malley & Richards, 2002; Michaelsen, Knight & Fink, 2002; Searle, Haidet, Kelly, Schneider, Seidel & Richards, 2003) and in business education (Michaelsen, Foml & Knight, 1997). In a study of the responses of 304 medical and dental students in an introductory course in medical science education in the United Arab Emirates 91% agreed with the statement “TBL increased the extent of my usual classroom involvement” and 33% of their open responses were categorised as “Small group learning: TBL is a great learning experience, motivating, enjoyable, different from the traditional lectures” (Abdelkhalek, Hussein, Gibbs, & Hamdy, 2010). Despite this very few mathematics lecturers use the approach.

We have previously argued, based on lecturer response as evidenced in task development, that there are sound theoretical reasons why TBL is particularly effective in promoting and developing a mathematical disposition and mathematical thinking and that it provides learning opportunities that are aligned with with social-constructivist learning theories and provokes mathematical thinking (Paterson & Sneddon, 2011). In this paper our focus is on student responses.

What is Team-Based Learning (TBL)?

TBL is a pedagogical model that shifts responsibility for learning to the students. The constitution of the teams is one of the key characteristics of this model. Teams usually have 5 - 7 students, and team membership is fixed for the duration of the course and work together on all team tests and tasks. Teams are not friendship groupings, but resemble the types of teams businesses construct to maximise productivity. Teams are constructed by the lecturer to distribute as fairly as possible the skills, knowledge and attributes needed to solve problems in the context of the course.

Students receive grades for course work in two different ways. Firstly, they prepare for each section of the course by reading carefully selected pre-readings and take a multiple choice test on this reading twice, once individually and once in their fixed teams. These are the readiness assurance tests or RAPs. When doing the test for the second time the students receive immediate feedback on their answers through the use of the Immediate Feedback Assessment Technique (IF-AT) These group tests are administered using IF-AT cards, on which four options are shown with the correct answer indicated by a star when covering is scratched off. If they are not correct first time they return to their discussion to gain part marks for being correct the second or even third time they 'scratch and win'. This immediate feedback means students always know the correct answers by the end of the RAPs. The power of immediate, goal-directed feedback has been identified in large-scale meta-studies by Hattie and Timperley (2007). Secondly they complete a team task that involves applying the ideas, concepts and skills learnt in the section. The structure of these tasks requires that all teams do the same task at the same time and that they submit one solution per team.

In 2009 and 2010 our focus was on course development and teaching of the Mathematics Education and Combinatorial Computing courses and the collection of data was largely opportunistic. We kept records of lecturer observations of class interactions, discussions between developers, and student evaluations. These evaluations were both Likert scale responses and open responses to the prompt " What helped or hindered your learning in this course?" In 2011 data was drawn from a parallel research project on Student Identity in mathematics involving the students in the Combinatorial Computing course. They were asked, amongst other things, about how they felt about TBL as a model of delivery. These interviews add an important dimension since they were conducted by impartial researchers not involved in teaching the TBL courses. In 2012 the data was augmented by audio recordings made in three situations: of two teams in Combinatorial Computing as they worked on tasks in class; two teams in the Dynamical systems course reflecting back on how they worked on the tasks in response to questions from an interviewer; and unstructured interviews with students from Combinatorial Computing that focussed on their experience of learning in a TBL environment.

We recognise that the fact that we are all enthusiastic implementers of the model may skew the outcomes and that this is a comparatively small study. We also acknowledge that we have, at times, pushed the envelope of the TBL structure to fit our mathematical needs.

Discussion

In the following discussion of Selden and Selden's (2001) questions, the data from all these sources are combined. While the learning experiences, content and lecturers in the three courses was different, we found the students' responses sufficient similarity to allow us to categorise them to begin to answer the questions. We note that students in the mathematics education course have completed at least three undergraduate mathematics courses and the students in the post graduate course will al have done a number of both pure and applied mathematics courses in their first degree. Unless otherwise indicated the direct quotes are from students in the undergraduate Combinatorial Computing cohorts, either from their open responses to evaluations or from the interviews. Quotes from students in the mathematics education course are coded ME and the Dynamical systems students are DS.

Question One: How might one change the classroom culture so students came to view mathematics, not as passively received knowledge, but as actively constructed knowledge?

It is our contention that TBL changes the classroom culture so students begin to view mathematics, not as passively received knowledge, but as actively constructed knowledge. What is happening as students work in established teams on a task or a problem that they have to work on together to succeed? The students talk about '*pooling their expertise'* and '*drawing on different people's ways of working*' and of the importance of learning to listen as others '*explain their thought processes (ME)'* and of the role that argumentation and defence of conjectures and ideas pay in reaching correct solutions. These behaviours align with the mathematical thinking described by Mason and co-authors (Mason, Burton and Stacey, 1982; Mason, 2008).).

The students say they find ideas are more accessible: "*I've certainly found it easier than my other level three papers. That could just be from the teaching strategy, the way it's been taught."* They valued the group discussion and the new arguments and perspectives they developed from working with their peers: "*It gave me alternative perspectives, ... coming from someone on my level rather than from a lecturer or from a text book"* and *"Working in a group you get to bounce ideas off of each other (ME)"* and *"it's just the whole environment where you can learn where you've gone wrong and you can correct it."* Not all the students felt they pushed themselves as much as they might have on their own: "*I found that I probably was lazier with the tasks than I otherwise would have been, had I had to do it myself."*

The responses to the pre-readings and RAPs were almost universally positive indicating that, when compelled, students value being better prepared to engage mathematically: "*I really liked the RAPs, sort of back to the primary school pre-test style of learning, it was really good." "I enjoy the idea of having to learn the definitions first and then learn the topic. I think that in particular is something that could be applied to almost all the math courses. That I really enjoy."* The frequent in-class assessment meant they needed to '*stay on the ball the whole time, no cruising till the end (ME)*." We suggest that these students showing an awareness of the need to be able to bring a knowledge of definitions to work on proving theorems and solving problems.

They also spoke about the feeing of accomplishment when the team was able to solve a problem no-one had been able to do alone: "*I remember at least one instance of our team when nobody got the right answer on the individual IRAP and then we all got it for the team RAP*." They refer to students bringing ideas from other parts of mathematics and that when they worked together the focus was on thinking: "*When we got together ..* ***thinking*** *(*her emphasis*) about it - it was better.*" An awareness developed of team member's strengths and that communication improved over time: "*We understood each other – we knew who's strong in what areas (DS)," "I can remember one instance when we were doing the tree traversal algorithms where I brought, I remember presenting them with a problem which they hadn't thought of, which I had from experience previously."* There are strong indications of their extending their personal example spaces (Watson & Mason, 2002a, 2002b) The following is typical of a number of responses in all three courses:

> *Someone else always has a different view on the mathematical searches than you have … it really makes you understand what you're talking about because sometimes you're so limited to your own way of thinking that if you look at it from another way, the solution is really easy but if you focus from your way then you get stuck at some point, … if you do it with four or five people solving exercises it's quite easy because a lot of knowledge and a lot of different views on the same thing and it really helps you to expand your way of thinking.*

*Question Two: What are the effects of (*various co-operative*) TBL learning strategies on student learning?*

> *This is like working with a team in the real world where we very seldom work on our own - co-operation is vital to any career… This idea of getting a good mark because you understand the material and not solely because you were aiming for a good mark is what all assessments should aim for. (ME)*

We can begin to answer this question from data collected when the interviewer asked each of the twelve students: "So thinking about the style of the course, it was a Team Based Learning approach, how did that fit in with your style of learning?" Of the 12 students interviewed ten responded positively, two had mixed feelings and none were negative. One of the two was the person who was concerned about being lazy and the other felt the team went too quickly and was dominated by a strong mathematician. The most interesting responses were from students who in the pre-interview were negative but shifted their perspective: "*I actually thought I was going to hate it. … I hate team work. … But I actually did like it. And I did actually enjoy it in the end. So maybe it is my style of learning, even though I didn't know it was. I liked it because actually you could talk about stuff"*

Team Based Learning encourages students to ask themselves questions. In the discussions about drawing a phase portrait the students in the Dynamical Systems class were heard saying a number of things the lecturer regarded as very useful, things she hoped they would be asking and observing: *"This direction doesn't match with that direction" "Choose a point and see where it goes" "How do you know that?" "Direction does matter" "Have you considered the eigenvectors?" "Does that make sense?" "What's the stable manifold doing? Is it just floating around?"* During the next lecture she gave the whole class this list.
There were however teams that functioned less effectively, particularly if students did not always come to class. One student commented: "*When we were actually doing the tasks we would have had perhaps four people really engaging with it. But then they weren't turning up to class for other things as well, the hangers on, so they were kind of special cases. Anomalies. I wouldn't put too much attention on them. Certainly other teams didn't have that kind of thing happening. It was just that we had this particular weird little set."* The mathematical language he uses to describe this is fascinating.

Question Three: What kinds of interactions are most productive?

> *From a constructivist point of view the instant feedback makes sense - to learn from our mistakes and adapt to our environment this kind of testing and working together is far more beneficial than a number out of 10 you receive a week later. (ME)*

A number of students commented on the value of the immediate feedback: "*It was great knowing immediately you were right"* and on the way that working with others either confirmed or disproved their ideas.

Arguments of various types played an important role in this. The usual sort of mathematical argument was mentioned frequently: "*If I can convince the other one my way is correct then I am sure my idea is correct*." Students who said they usually work alone found the opportunity to interact rewarding: "*Normally I avoid asking for help and talking to others. I* *try and get everything done on my own, researching online or studying the notes or the text book or trying to figure it out myself. And that normally works well for me, but it does take longer. Whereas this one, anything I didn't understand I felt my team mates were able to explain it adequately, and then it was good being able to argue about it, and discuss it and to attack a problem from different points of view. And to be able to see where the other person was coming from.*" A number of students referred to the usefulness of hearing someone explaining how they approached a problem.

There were more heated arguments: "*Though one member of my team and I did not quite get along as smoothly as we might have liked. And there may have been one or two very sort of heated team tasks. But a little aggressive stand offs may have been helpful in the mathematical learning … I was working very, very hard to do everything in my power to prove him wrong all the time. That sounded like a nasty thing to do. But it did make me more focussed, albeit for the wrong reasons."*

There were also instances when a team member who had not been part of a discussion needed more time than was available to be '*brought up to speed*" and in the end "*we had to convince the guy again and it took like five or ten minute extra to convince him … that point I was like okay, doesn't matter if you don't understand, just be quiet and work with us*" This raises the question of the role of the person who was seen as the team leader. If they were a strong mathematician whose focus was on gaining the maximum grade the interactions were less productive than when they collaborated willingly with the team. The recognition of "*playing to different people's strengths (DS)*" appears to be an important aspect in the creation of effective teams.

Some of the students who did not identify themselves as 'mathematicians' spoke about not always following the discussion but they said it was useful to be a '*listener*' and to hear the ideas being discussed by a number of people and not just by the lecturer: *"Certainly one of the tasks especially helped my understanding where one of the team members sort of went about the problem and something just clicked for me, to see someone do it that way and that really helped, counting symmetries."*

Question Four: Are some students advantaged while others are disadvantaged by the introduction of TBL** (cooperative learning)**?

Some of the more talented students expressed concern at being held back but the consensus was that "*Although at first it seemed that the groups might hold back students working at higher levels, they appear to have worked by encouraging these students to study the material in more depth - developing the breadth and depth of their knowledge rather than accelerating them through the curriculum.(ME)"* In fact the researchers in the Identity project from which we have drawn data observed that "Those who most strongly identified as mathematicians were most open to the team-based learning format." (Barton, Ell, Kensington-Miller & Thomas, 2012, p 4)

This is in contrast to a study of student performance in a medical gross anatomy and embryology course that found that the students who benefited most from TBL were the academically at-risk students "who are forced to study more consistently, are provided regular feedback on their preparedness and given the opportunity to develop higher reasoning skills" (Nieder, Parmelee, Stolfi &Hudes, 2005 p 56) This is supported by statements made by a music and mathematics major student who is dyslexic and has found mathematics very challenging. She said: "*I like to listen when others explain how they see the ideas and then I try to see the patterns as we solve the problem, I did better in this course than my other stage*

3 courses."

In another group there was a student who was finding the work hard and one of her team mates talks about her and the problem of helping someone when the interaction is being recorded: "*I think I was concerned about someone in my group because I think she wasn't as confident as say the rest of us in just putting our ideas out there. And I probably could have managed this better in terms of helping her and stuff, ... especially with the camera trained on you, you don't really want it to be recorded."* She helped her more at other times. Despite the negative feedback on the mode of data capture this does underline the sensitivity for one another's feelings evidenced.

Conclusion and Questions

The data presented largely supports our contention that implementing a Team Based Learning approach to delivering mathematics and mathematics education lectures can allow, and even prompt, the lecturer to create an environment in which students play a more active role in the construction of their mathematical knowledge and there is evidence that TBL serves both ends of the academic spectrum well.

TBL promises an effective alternative to the traditional mode of course delivery in higher mathematics. We would welcome further research that explores the use of TBL in large first year classes and quantitative studies on the impact of the model. We welcome the reviewers' questions and input and I will address them in the presentation and in the longer paper.

How do you create a classroom culture in which students came to view mathematics, not as passively received knowledge, but as actively constructed knowledge? What mathematical behaviours do you encourage in lectures? How do you do this?

References

Abdelkhalek, N., Hussein, A.,Gibbs, T. & Hamdy, H. (2010). Using team-based learning to prepare medical students for future problem-based learning. *Medical Teacher, 32*, 123 - 129.

Haidet P, O'Malley KJ, Richards BF. 2002. An initial experience with team learning in medical education. *Academic Medicine, 77,* 40-44.

Hattie, J. & Timperley, H. (2007 The Power of Feedback. *Review of Educational Research, 77* (1), 81 – 112.

Mason, J., Burton, L. & Stacey.K. (1982) *Thinking Mathematically.* Prentice-Hall.

Mason, J. (2008). Phenomenal Mathematics. Plenary presentation. *Proceedings of the 11th RUME Conference. San Diego*.

Michaelsen LK, Foml D, Knight A. 1997. Designing effective group activities: Lessons for classroom teaching and faculty development. In D. DeZure (ed.), *To improve the academic resources for faculty, instructional and organizational development.* Stillwater, OK: New Forums Press. pp 373–379.

Michaelsen, L.K., Knight, A.B., Fink, L.D. (2002). Team based learning: A transformative use of small groups in college teaching. Sterling, VA: Stylus Publishing.

Nieder, G.L., Parmlee, D.X., Stolfi, A. & Hudes, P.D. (2005). Team-based learning in a medical gross anatomy and embryology course. *Clinical Anatomy, 18* (1) 56 -63

Paterson, J. & Sneddon, J. (2011) Conversations about curriculum change: mathematical thinking and team-based learning in a discrete mathematics course*. Int. J. Math. Educ. Sci. Technol. 42*, (7), 879-889.

Searle, N.S., Haidet, P., Kelly, P.A., Schneider, V.F., Seidel, C.L. & Richards, B.F. (2003). TBL in medical education: Initial experiences at ten institutions. *Academic Medicine, 78*(10Suppl.), 55–58.

Selden, A., &Selden, J. (2001). Tertiary mathematics education research and its future. In D. Holton (Ed.) *The teaching and learning of mathematics at university level: An ICMI study* (pp. 207 -220). The Netherlands, Kluwer Academic Publishers.

Watson, A. & Mason, J. (2002a) Student generated examples in the learning of mathematics. *Canadian Journal of Science, Mathematics and Technology Education, 2* (2) 237 -249.

Watson, A. & Mason, J. (2002b) Extending example spaces as a learning/teaching strategy in mathematics. In A Cockburn and E.Nardi (Eds.) *Proceedings of the International Group for the Psychology of Mathematics Education, Norwich, UK, Vol. 4*, pp 377 – 385.