THE SOCIALLY RESPONSE-ABLE MATHEMATICS EDUCATION PROJECT

Storms and Tides Project

Teachers' Report on an Activity

Materials produced by Paul Fee

Introduction

Periodicity is a mathematics concept taught in Yr 10 trigonometry in the context of sine, cosine and tangent functions for rotational angles. Periodic graphs are drawn and compared. The concept is highly abstract and is not usually given practical applications. This project was able to harness this concept and enable students to use its power to investigate a real world problem of considerable significance to them.

Carnarvon is frequently threatened by tropical cyclones, although not often directly impacted. There appears to be evidence that tropical cyclones may be increasing in severity as a consequence of global warming.

Carnarvon has a system of levee banks designed to protect it against flooding by the Gascoyne River. It also has a recently constructed partial “surge wall” as protection against cyclone storm-surge.

Cyclone Vance, which impacted the neighbouring town of Exmouth in 1999 provides a case study of the possible consequences of severe tropical cyclone impact involving storm surge.

In this project, a group of Yr 10 students was asked to provide answers to the following questions:

1. What is a storm surge?
2. How does it relate to the normal tides?
3. Why is there a pattern to the astronomical tide and how can we define the pattern mathematically?
4. What was the behaviour of the tides during cyclone Vance?
5. How did this behaviour differ from the predicted tides?
6. What would have happened if the surge had occurred at high tide, low tide?
7. How unlucky/lucky was Exmouth?
8. If the same thing happened to Carnarvon how safe am I standing on my classroom floor?
9. What protection is afforded by the storm surge wall?
10. Should the Carnarvon community be considering a worst-case scenario?

It was assumed that the students would take for granted that the authorities would have assessed the threat, and that they are not at risk. Like the general population they know and accept the risk of storm wind damage, and are aware of the risk of Gascoyne River flood damage. The levee system protects the town against the “100 year flood”. However here has been no occurrence of serious cyclone surge in living memory.

At the conclusion of all the tasks, it was expected that the students would have enough information available to them to sensibly comment on the issue, and would present their findings to the community authorities.

Description of Activities

1 *Students plot a periodic sine wave*

As part of their normal year 10 trigonometry course, the functions for sine, cosine and tangent for rotational angles were plotted as a class exercise.

2 The moon and tides

The relationship between the moon and the tides was studied in science

3 The periodic nature of the tides

Tide tables for Carnarvon were viewed. (See Appendix 1) Data was graphed. It was noted that the saw-tooth shape of the graph fails to represent true nature of tidal flow.

4 Develop an algorithm

Carried out as a class exercise on the whiteboard. (See appendix 2)

5 What is storm surge?

Power-point presentation of Cyclone Vance.

6 Plot Exmouth predicted tide and separately plot the actual tide during Vance.

7 Enter data for storm surge and derive data for the worst case scenario. Generate graphs. (Appendix 3-4)

8. Learn to use a level; survey from benchmark to classroom (Appendix 5)

9. Visit surge wall and survey its height.

10. Report to Shire officers.

Implementation Timeline

This project was implemented in term 1 2009. The activities were carried out over a 3-week period. Some preparation for the final presentation was done in an English class. The Project was carried out in the normal maths teaching programme.

Student learning

<u>1. Mathematics</u>

1.1 *Periodicity.* This concept is quite abstract and does not normally elicit any interest from students, who produce the required graphs and move on. Several students were able to describe from their own experience how tidal flow differs from the saw-tooth model, (fishing being a No 1 past-time), and recognised the fact that a sine curve accurately represents the true situation.

1.2 *Algorithm.* The development of an algorithm to superimpose a sine curve on tide-table data proved to be the most difficult concept to teach. This was accomplished by plotting a giant sine curve on a whiteboard, and reducing the data to fit a scale range of zero to 1 (rather than -1 to +1). The x-axis intervals of 30 degrees fortuitously fitted the required hourly intervals of our tide-table graphs (i.e. there are approximately 6 hours between maximum and minimum tides; where this was not strictly true I fudged the data).

1.3 *Plotting data using Excel* (See appendix 3) The sets of data plotted were;

- Exmouth predicted high/low tides for 21st March 1999 to 23rd March 1999. This data was taken directly from the Australian Tides website and was rounded off to fit 6 hour intervals.
- Algorithm. The data was entered for 2.5 cycles starting from a maximum.
- Exmouth tidal range for 6 hour cycles
- Tidal minimum for 12 hour cycles
- Derived lunar tide, achieved by applying a formula involving product of algorithm and range + tidal minimum.
- Storm tide. Hourly data of actual tide experienced during the cyclone. (Data extracted from an internet graph by me).
- Storm surge. Arrived at by subtracting predicted tide from actual tide.

Graphs were generated of the predicted tide, storm tide and the algorithm itself, (see Appendix 4).

Worst case scenario was arrived at by translating the storm surge data 4 hours to make it coincide with the time of high tide, then adding the data to the lunar tide.

Some students were able to carry out these tasks after careful explanation. Some required step-by-step individual help and did not fully grasp the process. However, all were startled by the outcome. The process involved exposing the students to the ease of copying a formula relative to the position of the cells involved.

1.4 Survey levelling.

Although the mathematics is straightforward, involving only addition and subtraction, the concept of levelling is quite difficult to grasp, and definitely involves higher-order thinking. The students certainly thought this was "hard". The process was however enjoyable, accessible to all, and some students were totally engrossed in what they were doing.

The closest benchmark was of course outside the school grounds and involved a run of three long sightings, culminating at the floor of their classroom (altitude 4.97m. - see appendix 5) The trip to the surge wall gave us an altitude for that structure of only 2.5m and 2.6m.

2. Social learning

It was obvious to the students that this project raised issues of great importance to their community. When the students presented their findings to 2 senior representatives of the Carnarvon Shire, they were genuinely keen to impress, and were very interested to hear the Shire's reaction. The pressure on the students to perform well and to do their story justice was evident in the way they insisted on rehearsing the presentation several times, including once for the English teacher. The students knew that their investigation was significant and were very proud that the Shire representatives treated their presentation so seriously. The Shire engineer in particular congratulated them on their mathematical analysis. The Deputy Shire President agreed with the students that the threat to Carnarvon is very real, and that further works have to be carried out in the near future. He detailed the Shire's plans to the students, noticeably treating them as a knowledgeable audience.

3. Other issues

The engagement of the students in this project was clearly evident in the way they presented their findings publicly. Indeed it would be fair to say that the students were proud of what they had accomplished, (and so was I).

3.1 What went well

- The reaction of the students to the power of the spreadsheet showed that they were clearly impressed. Being able to produce the graph of the worst case scenario virtually at a keystroke (albeit after much data inputting and manipulation), caused general excitement.
- The students of course enjoyed getting out of the classroom doing the surveying. They were all willing to "have a go" and were very keen to be photographed doing so.

- The final public presentation caused a general onset of nerves, but the class was totally focused and very motivated. Several students were reluctant to directly report on specific maths content; they concentrated on the practical aspects of the project. The students who did present the mathematics used a data projector to demonstrate the spreadsheet and the generation of graphs. They did this very professionally, and it was noticeable that they had thoroughly prepared themselves.

3.2 What could be improved

In a real sense the assessment of this project was inherent in the final presentation. I was able to assess the relative contribution of different students but did not do so on a formal basis. Perhaps a rubric such as those used by the English teacher would have been appropriate, but I was more concerned about their performance as a group.

I should have included specific assessment related to the spreadsheet work. For example, I could have had them generate data and graphs for the scenario if Cyclone Vance had hit Carnarvon at that time on that day. This would have tested their understanding of the use of the algorithm for example. Similarly I could have given formal assessment of the use of the surveyors' level.

3.3 Investment of time

Of concern when undertaking a project of this nature, which interrupted my program for 3 weeks, was the feeling that I needed to justify it. Certainly, the program as originally envisioned was far too ambitious and convoluted. I managed to narrow my focus so that I felt comfortable that basically everything I was doing was deeply mathematical. Although the work towards the final presentation did not involve new mathematical learning per se, it certainly involved the students in clarifying their understanding in a very powerful way. They also had the opportunity to learn from each other.

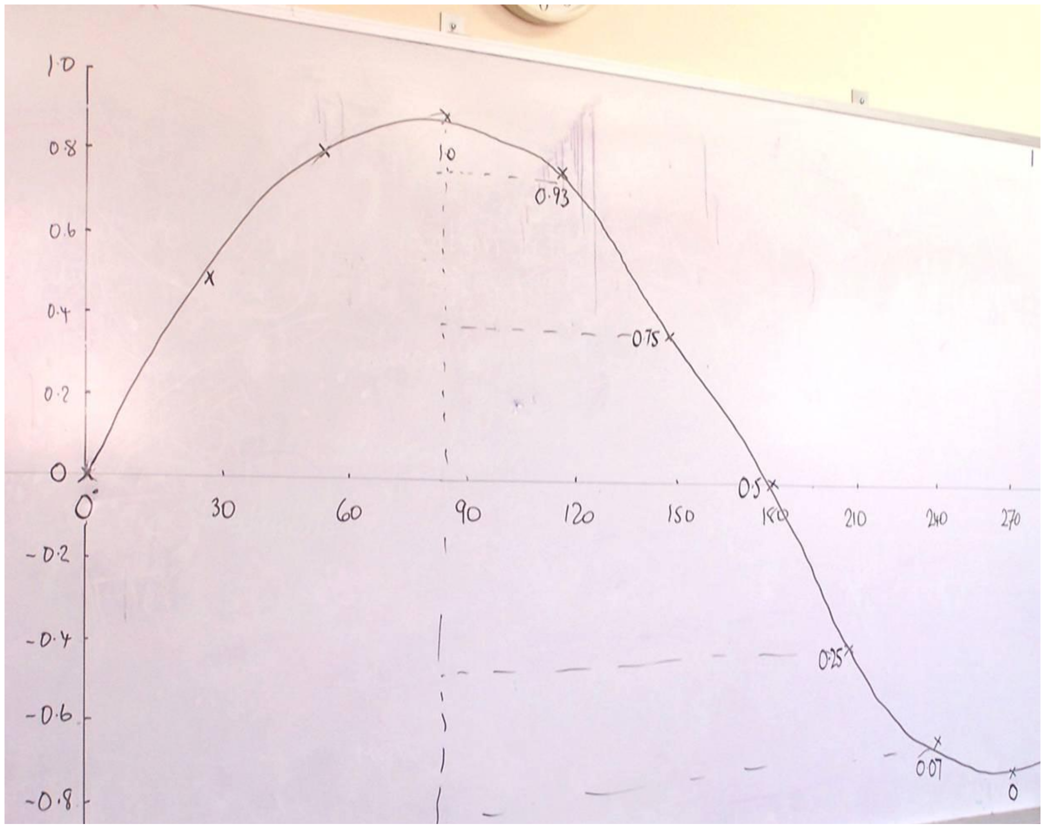
For many of these students, when they have left year 10, this is the mathematics they will remember.

Appendix 1

Sunday 8th Mar 2009	0.57m @ 3:09 AM 1.17m @ 10:33 AM 1.10m @ 1:49 PM 1.60m @ 8:12 PM
Monday 9th Mar 2009	0.53m @ 3:48 AM 1.30m @ 10:33 AM 0.96m @ 3:22 PM 1.63m @ 9:28 PM
Tuesday 10th Mar 2009	0.51m @ 4:19 AM 1.44m @ 10:54 AM 0.81m @ 4:15 PM 1.64m @ 10:27 PM
Wednesday 11th Mar 2009 Full Moon	0.52m @ 4:48 AM 1.58m @ 11:22 AM 0.69m @ 5:00 PM 1.62m @ 11:18 PM
Thursday 12th Mar 2009	0.54m @ 5:17 AM 1.69m @ 11:52 AM 0.60m @ 5:44 PM
Friday 13th Mar 2009	1.57m @ 12:04 AM 0.58m @ 5:46 AM 1.77m @ 12:21 PM 0.55m @ 6:25 PM
Saturday 14th Mar 2009	1.49m @ 12:46 AM 0.63m @ 6:15 AM 1.80m @ 12:48 PM 0.53m @ 7:05 PM

Appendix 2

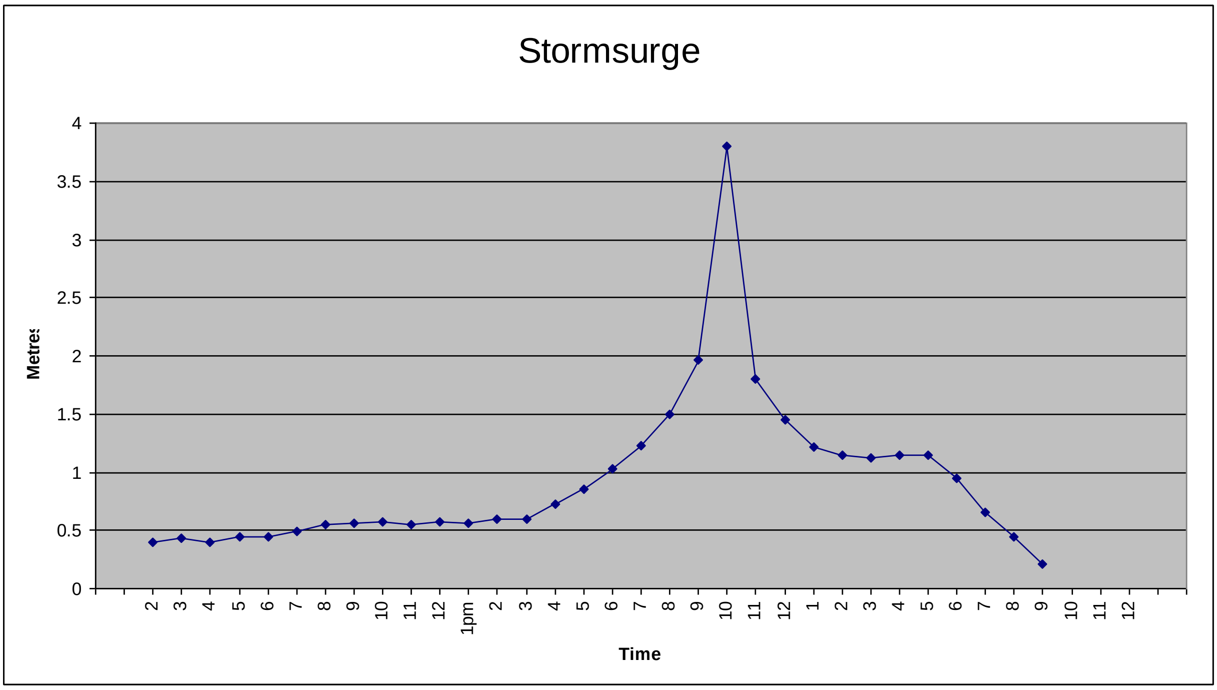
Algorithm for sine wave



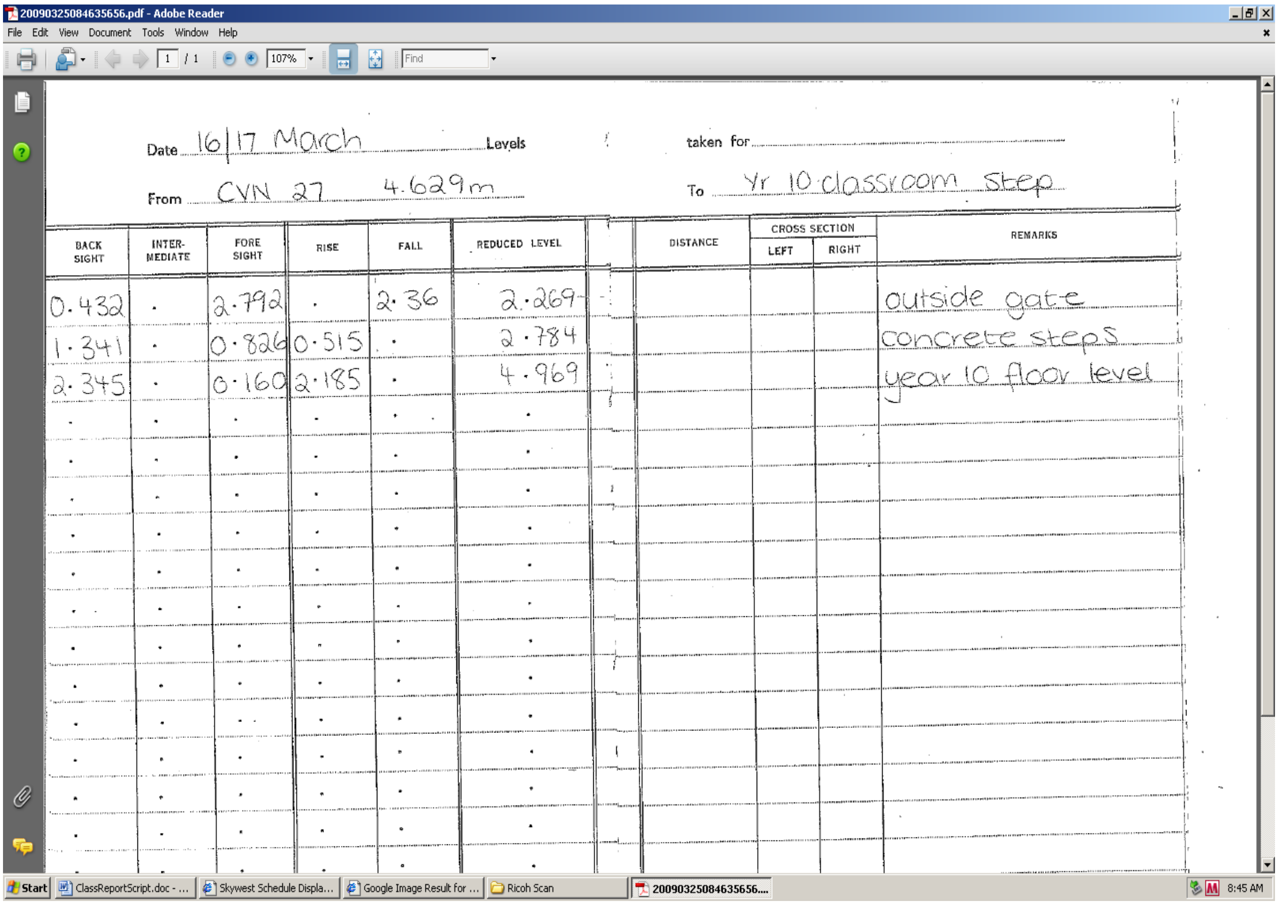
<u>Appendix 3</u> Spreadsheet (part)

Time	2	3	4	5	6	7	8	9	10	11	12	1pm	2	3	4	5	6	7	8	9	10	11
Tide Table	2.6						0.4						2.3						0.6			
StormTide	3	2.9	2.45	1.95	1.4	1.05	0.95	1.1	1.45	1.9	2.4	2.75	2.9	2.8	2.6	2.3	2.05	1.95	2.1	2.7	4.9	3.4
Stormsurge	0.4	0.43	0.4	0.45	0.45	0.5	0.55	0.57	0.58	0.55	0.58	0.56	0.6	0.6	0.73	0.85	1.03	1.23	1.5	1.96	3.8	1.8
Predicted Tide	2.6	2.47	2.05	1.5	0.95	0.55	0.4	0.53	0.88	1.35	1.83	2.19	2.3	2.2	1.88	1.45	1.03	0.72	0.6	0.74	1.1	1.6
Adjusted sine	1	0.94	0.75	0.5	0.25	0.07	0	0.07	0.25	0.5	0.75	0.94	1	0.94	0.75	0.5	0.25	0.07	0	0.07	0.25	0.5
Tide Range	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.9	1.9	1.9	1.9	1.9	1.9	1.7	1.7	1.7	1.7	1.7	1.7	2	2	2
Baseline	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
StormTide					1.35	0.99	0.8	0.98	1.33	1.85	2.38	2.75	2.88	2.75	2.45	2.01	1.63	1.32	1.33	1.59	2.13	2.83
Stormsurge					0.4	0.43	0.4	0.45	0.45	0.5	0.55	0.57	0.58	0.55	0.58	0.56	0.6	0.6	0.73	0.85	1.03	1.23
Predicted Tide	2.6	2.47	2.05	1.5	0.95	0.55	0.4	0.53	0.88	1.35	1.83	2.19	2.3	2.2	1.88	1.45	1.03	0.72	0.6	0.74	1.1	1.6

Appendix 4 Graph of storm surge



Appendix 5 Student survey data sheet



Date 16/17 March Levels taken for

From CVN 27 4.629m To Yr 10 classroom step

BACK SIGHT	INTER-MEDIATE	FORE SIGHT	RISE	FALL	REDUCED LEVEL	DISTANCE	CROSS SECTION LEFT	CROSS SECTION RIGHT	REMARKS
0.432		2.792		2.36	2.269				outside gate
1.341		0.826	0.515		2.784				concrete steps
2.345		0.160	2.185		4.969				year 10 floor level