Possibilities of the Parabola

*Robyn Gibson
robyn.gibson@sydney.edu.au
Melissa Silk
17 Bedford Crescent, Dulwich Hill, NSW, 2203, Australia
MelissaCatherine.Silk@student.uts.edu.au

Abstract

Our story involves a bunch of junior high school students learning Cartesian plotting and graphing in order to understand the mathematics of a parabolic curve. Further exploration of the curve led to the development of a design project called "Possibilities of the Parabola" within which the parabolic curve served as a foundation shape for the creation of three-dimensional aesthetic objects. The objects themselves were related to the concept of *vessel*. That is, a container, a receptacle, a holder of something. The students were not to lose sight of the parabola but rather, embed the curve into their designs. As the project progressed, they experienced the joy in making that was interconnected to their studies in mathematics.

Introduction

Our observation as teachers working in cross-curricular settings led us to believe that students grow to recognize the way mathematics intersects with creativity when they are given the freedom to explore the points of intersection more directly. In the development of the Possibilities of the Parabola (PoP) course, we aimed to actualize an aesthetic experience based on melding explicit math theory with creating and making. An aesthetic experience in an education context must be motivated by stimulating action, exploration, awareness and surprise for it to be worthwhile and evocative [1]. This element of surprise was new to our students. They were more familiar with the idea of learning being a somewhat segregated experience. Therefore, using the parabola for inspiration to drive the explorations through two and three dimensional art/design projects was a totally new experience for all of us. Ultimately, we wanted the students to gain an understanding of mathematics in a new way and perhaps release them from the general view held by many that the study of math is not related to a positive aesthetic experience.

Background

There were many visually aesthetic factors to consider if we were to succeed in creating beautiful objects through the application of elegant mathematical curves. Considerations such as which parabola to use, what section of the curve to use, how to transform the line into a closed shape and how to iterate the shape into a form that passed for a vessel, were all addressed in the design development. These decisions were affected by questions relating to material choice, color and texture in addition to design constraints outlined in the original brief, specifically the restriction of the use of adhesives. In our teaching, we find that constraints often lead to increased creative problem solving and the possibility of more memorable learning.

The beginning. After our initial research related to applications of the parabola in industrial settings, we started physically plotting the curve by hand before moving into digital mathematical experiments (Figure 1). Our 2D experiments not only required an understanding of numeric values used to create the parabolic curve but also how the elements and principles of design can be applied to create interesting patterns and shapes. Figure 2 shows the way in which one curve can be iterated to create an elegant shape (reminiscent of Spirograph hypotrochoids, although this particular vector graphic was made digitally by applying simple iterative rotations to the curved line without the application of gears). In this case, the student experimented with $y = x^2$ using 1° rotation increments around an end point of the curve.

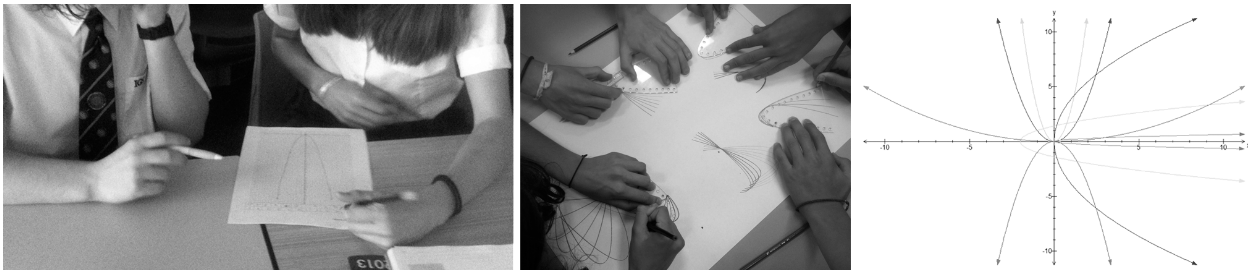

Figure 1: *Students plotting, graphing and manipulating the Parabola, manually and digitally.*

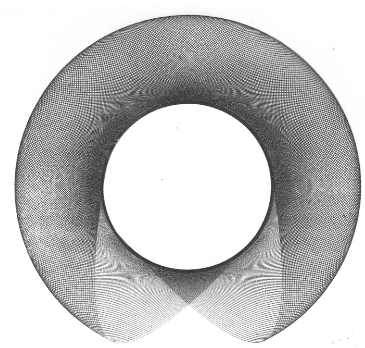

Figure 2: *Intaglio using* $y = x^2$

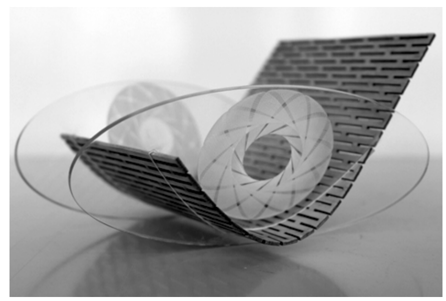

Figure 3: *Surface embellishment using* $y = x^2$

The middle. Many of the 2D visuals were applied as a decorative embellishment on the 3D vessel surfaces, as seen in Figure 3. Figure 3 displays a surface engraving made by manipulating a parabola in 2D. Vessel, being defined as a container, a receptacle or a holder of something guided the functional criteria of the PoP project. Construction without glue required the application of additional math in the way the vessel components were designed and made. Altering the dimensions of intersecting components differed by a fraction of a millimeter in order to provide tension and strength in the vessel form. When developing the designs for laser cutting, students were required to use one parabola as a foundation line to be continued to make a vector path which, when closed, would form the final shape for their vessels. Cutting and engraving took place within a single use of the laser cutter. Figure 4 shows an early experiment exploring how to form a shape around a single parabola. In this instance, the line indicates the path to be cut by laser technology.

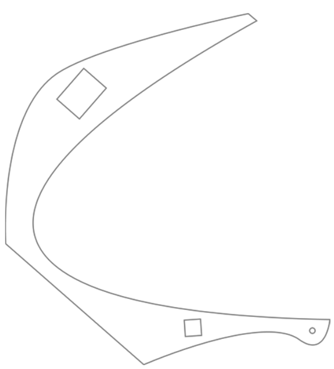

Figure 4: *Parabola shape.*

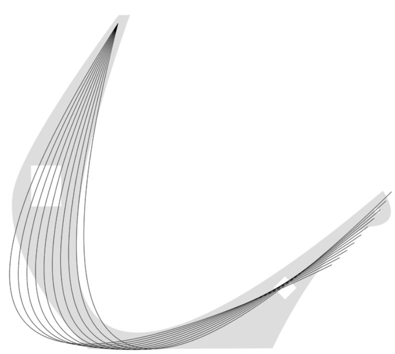

Figure 5: *Engrave and cut lines*

Figure 6: *Realized vessel experiment.*

The same shape is also visible as the solid area shown in Figure 5, however it is rotated to display the design of the horizontal lower edge, which formed a stable base for the work. When the solid shape was cut, some sections of the engraved lines became redundant. This was a decorative decision referring to the original foundation parabola rotated ten times on a chosen point along the line, near the lower right square shape. In this experiment, only the front and back vertical pieces were engraved, providing a surface embellishment for the vessel (Figure 6). As PoP evolved, we experimented with alternative ways of creating the parabola in our vessel designs such as utilizing reductive techniques, where we removed internal sections of a material in order to reduce stiffness, allowing rigidity to curve (Figure 7).

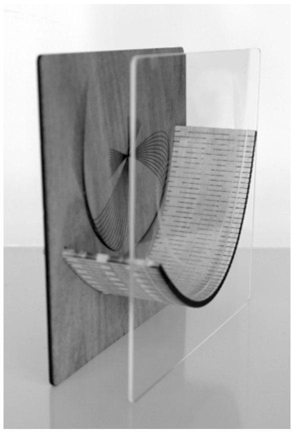

Figure 7: *Curving the ply by reduction technique.*

The themes of beauty, symmetry, iteration and elegance remained constants during both mathematical and artistic investigations. These themes *and* the parabolic curve can be seen in the samples in Figure 8. The parabola is evident and the structures are strong and stable. However, when students chose to base their designs on a section of the curve only, the parabola is not so distinctly present in the design. Figure 9 displays works created using a section of the parabola, held fast by tension or restriction in the form of wire, fabricated fasteners or rods. It is more difficult to identify the curve yet the aesthetic criteria are still addressed in the pleasing design.

Our goal was to encourage students to make a connection between math and the arts in a unique and positive way in order to augment their educational experiences. Stylianou & Grzegorczyk, researchers in the area of teaching math through liberal arts, provide findings that display an improvement in student attitudes towards mathematics and its relevance to their lives in general, when math themes such as symmetry are explored through abstract artistic creation [2]. The parabola was the inspiration for all student vessel designs. They were able to understand the variables that make this curve "fatter" or "thinner", identifying and visually articulating this through their vessel designs.

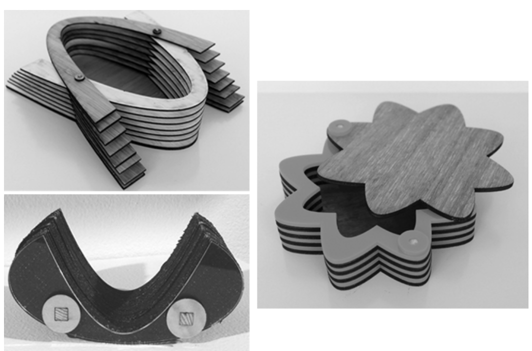

Figure 8: *Student vessel designs*

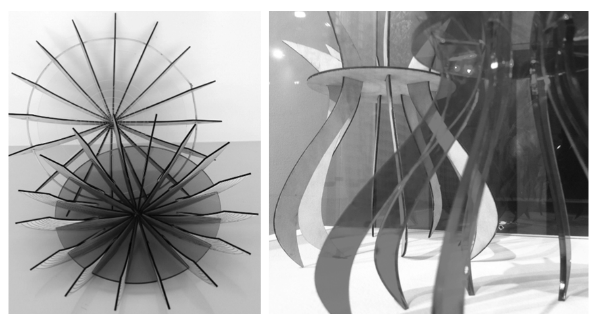

Figure 9: *Vessel designs from parabola sections.*

The end. Emerging technologies led us to experiments with more conceptual parametric modeling software to communicate with 3D printing technology. Students were supplied with a set of pre-prepared guidelines for using specific digital modeling tools and then let loose to experiment again with the elements and principles of design such as repetition, rotation, scale, balance and emphasis, to create the *vesselesque* works. The results of these explorations are very attractive. The transferable applications of these designs to real-world structures were discussed and some students went on to use these ideas in senior engineering/design projects. Figure 9 shows some samples of printed experiments formed by manipulating the parabola (or section of) within 3D modeling software. Again, the students started by creating a parabolic curve, then completed and closed a path in order to apply volume to the 2D shape. The 3D forms were created by manipulating the single shape in the same way as the former designs however the iteration took place within the software and not by manual construction techniques. This part of our learning was experimental and the range of designs produced was surprisingly varied. There was solidity as well as weightlessness in the work, with the parabola mostly recognizable as in Figure 9.

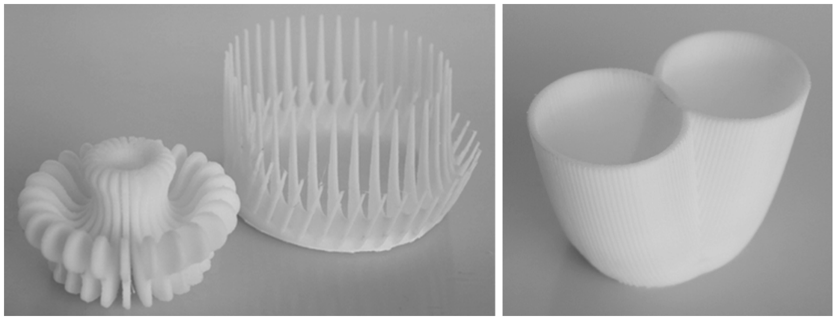

Figure 9: *3D printed designs for the PoP project.*

The student voice. The fruits of student learning were assessed and analyzed by detailed pre and post student questionnaires as well as audience feedback, post exhibition. Students discussed levels of engagement in math activities as well as the changes in pre and post understanding of terminology such as elegance, specifically the way this term can be applied to both mathematics *and* art/design. Around 75% of students gained a better understanding of aesthetics and about a third of those could describe the immersion in the PoP project as an aesthetic experience in itself. Comments about the relationship between math and art/design propose it "is a helping relationship, where one assists the other" and, "the PoP course has been a stepping stone into my future math(s) courses on parabolas". Frequently occurring adjectives within the audience feedback include "sophisticated, elegant and intelligent". Observers were able to identify the parabolic curve inherent in the designs and most agreed that the students had done a good job of showing how math can be beautiful as seen in Figure 7. Our journey into cross-curricular territory in this way allowed both teacher and student to engage with subject-centered education. Parker Palmer elaborates on the idea of subject-centered education in his consideration of this environment to be modeled on the "community of truth, this is a classroom in which the best features of teacher and student-centered education are merged and transcended by putting not teacher, not student, but *subject* at the center of our attention" [3]. For us, the subject was the parabola and what we produced is a stunning example of its possibilities in the hands of fresh minds and nimble hands.

References

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[2] D. A. Stylianou, & I Grzegorczyk, *Symmetry in mathematics and art: An exploration of an art venue for mathematics learning*. Primus, 15(1), 30-34. 2005.

[3] P. J. Palmer, The courage to teach. San Francisco: Jossey-Bass Inc. Publishers. P.116. 1998