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ART IN THE MIDDLE SCHOOL MATHEMATICS CLASSROOM:
A CASE STUDY EXPLORING ITS EFFECT ON MOTIVATION

A MASTER'S THESIS

BY

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To Yeşim...

ART IN THE MIDDLE SCHOOL MATHEMATICS CLASSROOM:
A CASE STUDY EXPLORING ITS EFFECT ON MOTIVATION

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ART IN THE MIDDLE SCHOOL MATHEMATICS CLASSROOM:
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May 6, 2013

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ABSTRACT

ART IN THE MIDDLE SCHOOL MATHEMATICS CLASSROOM: A CASE STUDY EXPLORING ITS EFFECT ON MOTIVATION

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May 2013

The purpose of this mixed methods study was to explore and understand how the use of art-based mathematical activities affected motivation of grade 7 mathematics students in Turkey. Activities were used in one lesson a week for six weeks. Pre- and post-surveys measured students' enjoyment, self-efficacy, and academic effort. Data were collected during the intervention period through focus group discussions. The discussions and survey results highlighted the key informants for interviewing. The statistical analysis indicates that using such activities in the classroom gives rise to no significant change, positive or negative, on the three constraints: enjoyment, self-efficacy and academic effort. However, group discussions and interviews of the key informants suggest that some students were affected by the intervention. Students with analytical aptitudes experienced a decrease in motivation; those who liked art were inspired and motivated. Integration of mathematics and art allowed students to view mathematics from a wider perspective than before the intervention.

Key words: art-based mathematics, enjoyment, self-efficacy, academic effort

ÖZET

ORTAOKUL MATEMATİK DERSİNDE SANAT: MOTİVASYONA ETKİSİNİN İNCELENMESİ KONUSUNDA DURUM ÇALIŞMASI

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Bu çalışmanın amacı sanatla ilintili matematiksel etkinliklerin özel bir okuldaki 7. sınıf öğrencilerinin matematiğe karşı motivasyonlarını nasıl etkilediğini araştırmaktır. Çalışmada anket, mülakat ve odak grup çalışması kullanılmıştır. Etkinlikler haftada bir saat olarak, 6 hafta sürmüştür. Anketle öğrencilerin etkinliklerden önce ve sonraki matematikten hoşlanma düzeyleri, öz-yeterlik dereceleri ve akademik gayret düzeyleri ölçülmüştür. Odak grup tartışmaları yoluyla da veri toplanmış, odak grup tartışmaları ve anket verileri yardımıyla mülakat yapıp öğrenciler belirlenmiştir. Sonuçlar etkinliklerden dolayı araştırılan üç boyutla ilgili (matematikten hoşlanma, öz-yeterlilik ve akademik gayret) öğrencilerde anlamlı bir değişme olmadığını göstermiştir. Ancak odak grup tartışmaları ve mülakatlar bazı öğrencilerin etkinliklerden olumlu olarak etkilendiğini ve matematiğin doğası hakkında daha kapsayıcı bir anlayış geliştirdiklerini göstermiştir. Analitik eğilimli öğrencilerin etkinliklerden olumsuz, sanat ve estetik eğilimli öğrencilerin ise etkinliklerden olumlu etkilendiğini ortaya çıkarmıştır.

Anahtar Kelimeler: sanatla ilintili matematik, hoşlanma, öz-yeterlilik, akademik gayret

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CHAPTER 1: INTRODUCTION

Introduction

I have wanted to teach for as long as I can remember. Deciding what subject to teach was far more difficult. I couldn't decide if it should be art or mathematics. Not only was I interested in both subjects, but I had ability too. Like many others, I believed the two disciplines were far removed from each other. I decided to teach mathematics because there was a shortage of mathematics teachers and I knew I would always be able to find employment. After all, mathematics was the more important subject and I could always carry on with art as a hobby. Obviously, at that young age, my thoughts were mirroring that of my family and the society I lived in. I had to discontinue my art classes in order to pursue mathematics.

In my 22 years of teaching, I have come to realise that there is much that connects the two disciplines and have collected many resources to this end. My love and passion for this interdisciplinary area and teaching has led me to this thesis. I hope that by encouraging teachers to bring more art into mathematics lessons I can help prevent other young adults from having to make such a decisive choice between the two.

Background

The importance of mathematics is widely recognised and yet much of the population appears to dislike it or find it difficult. The role of mathematics teachers is challenging. Not only must they enable learning of the many concepts and skills, but

also instill a love and interest for the subject. In *Principles and Standards for School Mathematics* (NCTM, 2000), the following is stated:

Middle-grades students should see mathematics as an exciting, useful, and creative field of study. As they enter adolescence, students experience physical, emotional, and intellectual changes that mark the middle grades as a significant transition point in their lives. During this time, many students will solidify conceptions about themselves as learners of mathematics—about their competence, their attitude, and their interest and motivation. These conceptions will influence how they approach the study of mathematics in later years, which will in turn influence their life opportunities (p. 211).

Students' decisions on high school electives are formulated in middle school.

Therefore it is paramount that students be given every opportunity to understand and appreciate the true scope of the nature of mathematics during their middle school years.

Furthermore, it is widely accepted that creativity is considered an important attribute in the workforce. There are claims that educators who use creativity in their teaching are more likely to create environments that foster higher order thinking skills which, in turn, may enhance the creativity of students. A teacher may also enhance students' creative ability by enabling them to feel a sense of joy in learning mathematics because "the greater a child's intrinsic motivation, the greater the likelihood of creative applications and discoveries" (Mann, 2005, p. 22).

Many students see mathematics as a completely separate discipline from art. They do not believe that mathematics has an association with beauty. There is an increasing trend towards interdisciplinary education so that subjects are no longer perceived as isolated and more real life connections can be made with school subjects.

Unfortunately, mathematics in real life is often considered to be confined to the statistical tools it offers: often yielding little more than bar graphs and pie charts. By connecting mathematics and art, not only is there a chance to see the aesthetical beauty that mathematics can produce but also a wider perspective of interdisciplinary connections between mathematics and real life.

Problem

Using art-inspired activities in mathematics can create a powerful learning experience and it is reasonable to expect that academic understanding, motivation and achievement can be enhanced through such activities. Research shows that enjoyment and interest are necessary for motivation (Shaffer, 1997; Singh, Granville, & Dika, 2002). However, there is little research about the effects of using art in mathematics with regards to student motivation, particularly with respect to the middle school classroom.

Purpose

The main purpose of this mixed methods study was to explore and understand how the use of art-based mathematical activities affects the motivation of grade 7 mathematics students in a private school in Turkey, and thus possibly gain some general insight into the motivation of middle school students.

Research questions

The study addressed the following main research question:

1. How does the use of art-based mathematical activities affect the motivation of grade 7 mathematics students in a private school in Turkey?

The following sub-questions were used to address this main question.

- a. How do art-based mathematical activities used in mathematics lessons affect grade 7 students with respect to their enjoyment of mathematics?
- b. How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their self-efficacy?
- c. How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their academic effort?
- d. What are the beliefs of grade 7 students with respect to their conception of the nature of mathematics?

Significance

This study contributes to the current research on the educational value of integrating the disciplines of mathematics and art. By giving further insights into the ways in which students respond to art-based mathematical activities, teachers of middle school mathematics could consider the ways in which interdisciplinary activities might aid both teaching and understanding. Furthermore, this study will enable teachers to reach out to some of those students who lack enjoyment, self-efficacy and academic effort with regards to mathematics. For students who are more artistic than analytic, the use of art-based mathematics in lessons may open a new gateway into mathematics thus making the subject more accessible.

It may be of particular interest to teachers in Turkey, as there is a lack of research and resources on the use of art-based mathematical activities in Turkish context.

Definition of key terms

Middle school: grades 6 to 8.

Self- efficacy: a belief in one's abilities to attain certain goals.

Motivation: the desire or willingness to do something.

Intrinsic motivation: motivation that arises from internal factors such as one's interest or enjoyment in a task itself.

Extrinsic motivation: motivation that arises from external factors such as rewards or punishments.

Academic enjoyment: the act or state of receiving pleasure from engagement in an academic task.

Academic effort: "an academic behavior requiring the demonstration of extra energy and hard work to accomplish personal goals pursued in a particular discipline"

(Sakız, 2007, p.23).

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

There are many resources on the connecting art and mathematics, some of which are related to teaching (Boles & Newman, 1990; El-Said & Parman, 1976; Field, 1997; Harker, 2009; Kappraff, 1991; Mitchell, 2005; Murray, 1994; Sanders, 2003).

Though there are studies which refer to the use of art-based activities for increasing understanding in mathematics classes, few focus on their effect on motivation in general, and fewer on student motivation in a middle school mathematics classroom (Alagic, 2009; Hanson, 2002; Harker, 2009; Healy, 2004; Sendova & Grkovska, 2005; Shaffer, 1997).

This study intends to explore and understand the effect of using art-based mathematical activities in grade 7 mathematics lessons. Enjoyment, self-efficacy and academic effort will be the focus of the study. In addition, students' conception of the nature of mathematics will be examined.

The challenge of middle school

Middle school mathematics is mainly about computation, with each grade consisting of a slight extension of the work covered in previous grades (Hanson, 2002; Sendova & Grkovska, 2005). For many students, it is seen as a set of correct steps with predetermined answers. Many students see it as lacking in interest and discovery and therefore, many students have a negative perception of mathematics (Healy, 2004; Odom, 2010).

Students in middle school are at a unique point in their life. As young adolescents, they have a great capacity for thinking and discovery. Early interest and achievement in mathematics are critical for success in mathematics at later stages. Studies have shown that interest improves motivation which, in turn, helps students learn (Healy, 2004; Singh, et al., 2002).

There is much support for a renewed curriculum with diversified instruction across many countries in middle school mathematics (Healy, 2004; Sendova & Grkovska, 2005). Teachers should provide learning where mathematics is challenging, exploratory, integrated, interesting and exciting. Activities need to be differentiated, varied and open-ended in order to sustain interest. Understanding and communication are paramount, as are connections to real life (Bier, 2010; Biller, 1995; Hannula, 2006; Hanson, 2002; Healy, 2004; Sendova & Grkovska, 2005). With regards to middle school students, their interest and motivation were seen to be the most pertinent predictors of achievement by Singh, Granville, and Dika (2002). Therefore removing boredom from middle school mathematics appears to be a necessity.

The relationship between mathematics and art

The historical aspect

Despite the common perception of their being two separate disciplines, mathematics and art have, in fact, a far reaching overlapping history. Ancient Egyptians and Greeks were familiar with the golden ratio (also known as the divine proportion) as can be seen on examination of the Great Pyramid of Giza and the Parthenon (Willingham, 2012). In fact, the golden ratio has been used extensively and is seen in

the work of many Renaissance painters such as Leonardo da Vinci's Mona Lisa (see Figure 1) (Boles & Newman, 1990; Emmer, 1994; Field, 1997; Kappraff, 1991).

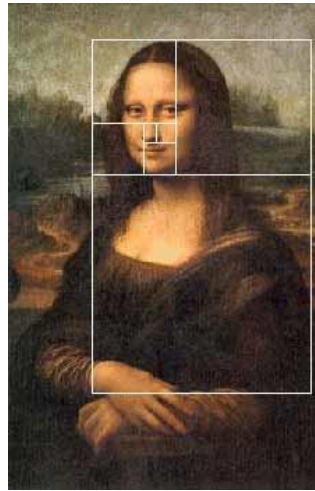


Figure 1. The Mona Lisa by Leonardo da Vinci, showing the golden ratio.

Mathematics was important in the everyday lives of craftsmen during the Renaissance period, who were known as practical mathematicians. During this period, many well-known artists (such as Piero della Francesca, Albrecht Dürer and Leonardo da Vinci) were also reputable mathematicians showing that art and mathematics were not considered separate disciplines at that time. Piero della Francesca was particularly interested in the theoretical study of perspectives, illustrated in many of his works of art, one example of which is seen in Figure 2. Perspective was in fact art's contribution to mathematics, thus changing scholarly mathematicians' notion of geometry (Field, 1997).

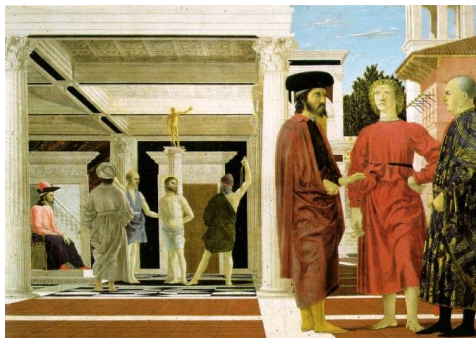


Figure 2. Flagellation of Christ by Piero della Francesca

Islamic Art is another area rich in both disciplines (Bier, 2010; Emmer, 1994; Field & Golubitsky, 1992; Kappraff, 1991; Özdural, 2000). In fact, Özdural highlights the collaboration of mathematicians and artisans during the medieval Islamic period. As a result of such collaboration, it was possible to obtain elaborate geometric patterns, as seen in Figure 3 below, from relatively simple shapes.

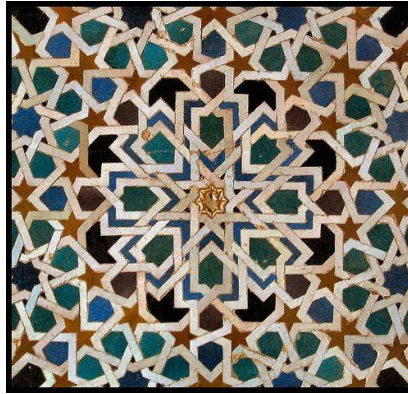


Figure 3. An Islamic pattern from the Alhambra Palace

One of the most impressive artists of mathematically-inspired work is Escher (Fellows, 1995; Schattschneider, 2004). Although his work is relatively recent, it did cover a variety of mathematical fields, the most well-known being impossible figures, such as in Figure 4, and tessellations. Escher was a non-mathematician who used intuition to guide him, though he was known to collaborate with the mathematician Roger Penrose on occasion (Emmer, 1994).

There are many other examples of the connection between the two disciplines throughout history. The examples given here only pertain to give an indication of some of these.



Figure 4. Belvedere by M.C. Escher

Connecting the disciplines

There have been many arguments about the relevance and importance of art to mathematics or mathematics to art (Biller, 1995; Emmer, 1994; Hickman & Huckstep, 2003). There is a considerable body of people who believe that the connection is valid and important (Alagic, 2009; Biller, 1995; Boles & Newman, 1990; Emmer, 1994; Field, 1997). In fact, there are numerous journals and organizations which exist to promote the relationship between mathematics and art. The International Society of the Arts, Mathematics, and Architecture (www.isama.org) and The Bridges Organisation (www.bridgesmathart.org) hold annual conferences to further these interdisciplinary connections.

Emmer (1994) and Kappraff (1991) cite examples of mathematics inspiring artwork and visual art aiding understanding of abstract mathematical concepts, and even introducing new ones. Others liken the patterns of mathematics to those of art and believe that the methods of reasoning in the two disciplines are similar (Biller, 1995). Indeed, some argue that the advancement of computer science has led to greater visualization than ever before, making the connection between mathematics and art even more tangible and concrete. Fractals, as seen in Figure 5, would not have

received such attention had it not been for computers and artists' sensibilities (Emmer, 1994).



Figure 5. An example of a fractal.

New areas of study, such as visual mathematics, algorithmic art, and design science show that the overlap between the two disciplines is once more gaining recognition. Nonetheless, symmetry and geometry are still prominent areas for the connection (El-Said & Parman, 1976; Emmer, 1994; Field & Golubitsky, 1992; Kappraff, 1991). As Boles & Newman (1990) state, “geometry *defines* relationships in space. Art *creates* relationships in space” (p. xvi).

With such an overlap between mathematics and art, the lack of integration in schools begs for attention (Hanson, 2002). When mathematics is integrated with other subjects in school, it is usually used as a statistical tool in science or the humanities. For many, art is not viewed as an academic subject. It is seen as fun and relaxing and many mathematics teachers fail to see the relevance; particularly when exam pressures are involved. Another reason may be that there is a lack of recognition of students' different intelligences (Healy, 2004). This issue will be discussed in more detail below.

The effects of art on mathematical learning

Most of the research on the use of art in mathematics lessons focuses on academic issues. There is evidence suggesting that mathematical understanding increases with the use of art-based activities (Hanson, 2002; Healy, 2004; Shaffer, 1997). Numerous reasons are given for this. One is that art-based activities adapt better to a student's own learning style (Alagic, 2009; Hanson, 2002; Harker, 2009). Visual art links mathematics to other subjects and real life as well, allowing students to make connections that may be otherwise missed (Alagic, 2009; Hanson, 2002; Healy, 2004). Harker (2009) goes on to state that mathematics-inspired art can lead to mathematical insight beyond the ideas it from which it originated. Using art in mathematics can also be a reason for students to go beyond their curriculum level as they strive to bring their ideas to life and, in doing so, take ownership of the mathematical ideas, developing intuition along the way (Sendova & Grkovska, 2005; Harker, 2009). Figure 6 shows an example of a student-created tessellation which uses translation.

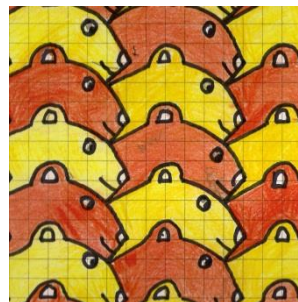


Figure 6. A student created Escher-like tessellation.

Another reason for increased understanding may be that expression is important for students because it allows for the internalization of ideas and concepts before being able to represent them externally (Shaffer, 1997). Not only does art-based mathematics increase analytical thinking, but it also provides students with their own ways of remembering, and a visual explanation of abstract mathematics (Hanson,

2002; Harker, 2009). Furthermore, by integrating mathematics and art, visual awareness is increased (Bier, 2010). Which, in turn, enriches students' perception of the world. Another important aspect is that learning mathematics through art can help those students who feel alienated by traditional teaching and instruction (Shaffer, 1997).

In addition to the academic aspect, using art in mathematics balances imagination and creativity with logic whilst showing that mathematics can be a source of beauty (Bier, 2010; Hanson, 2002; Healy, 2004; Harker, 2009). However, creating situations that aid students' competence to transfer concepts from one representation to another (e.g., pictures, objects, symbols and real-life context) is not an easy task (Alagic, 2009). Therefore, activities should be chosen carefully so that they support concept development and deeper understanding of mathematical principles. Figure 7 shows an example of origami which can allow students better understanding of geometric principles and can aid spatial awareness. Spatial awareness is improved by allowing students to experience concrete three-dimensional representations of what would otherwise be their interpretation of drawings of the solids. Furthermore, the folding of the units allows them to understand the physical properties of terms such as parallel, horizontal, diagonal, angle bisector and so forth.



Figure 7. A truncated dodecahedron made with unit origami

In her article about using Turkmen carpets to explore mathematics in the classroom, Bier (2010) refers to the students' excitement in recognizing patterns. Shaffer (1997) notes similar excitement when students created art work in an experiment at the mathematics studio workshops. However, the excitement here was due to learning mathematics with "the freedom and joy associated with art-making" (p.96). His results showed that 67% of the students reported having more positive attitudes toward mathematics after these workshops. Students professed to liking mathematics more and made comments about mathematics not seeming as complicated or difficult as before. They also preferred the control that they had over their learning.

The use of technology in art-inspired mathematics

Computer graphics can play a substantial role in making mathematics visual. They can help investigate areas that are difficult and cumbersome to do otherwise, thus bringing about better understanding (Emmer, 1994; Field & Golubitsky, 1992; Sendova & Grkovska, 2005; Shaffer, 1997). Shaffer's (1997) research found that computers could be an effective component for the students doing mathematics and art. "The ability to change a design quickly, easily, and in a continuous fashion contributed not only to the development of intuition, but also a sense of control over their work" (p. 109).

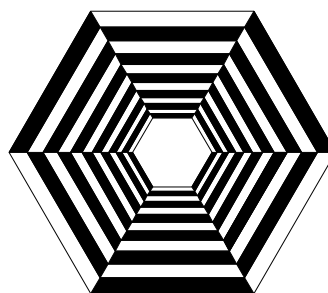


Figure 8. Op-art created with Geometer's Sketchpad by a grade 7 student.

Students were able to change their minds about their work, and correct mistakes, quickly and easily. “The computer provided a forgiving environment in which students could explore freely” (Shaffer, 1997, p.109). However, Shaffer concludes that computers were neither necessary nor sufficient for the success of students in his workshops. Two particularly useful pieces of software for creating mathematically-inspired art-work in middle school are Geometer’s Sketchpad (see Figure 8) and Logo.

Motivation

This study is based on the premise that middle school students’ conception of the nature of mathematics and their enjoyment, self-efficacy and academic effort can be improved by appropriate experiences connecting art and mathematics. Because enjoyment, self-efficacy and effort are conceptually related to one’s motivation, theories of motivation can be useful to understand the relationship between these constructs (enjoyment, self-efficacy and effort) and the planned research intervention on the connection between mathematics and art.

In general terms, motivation is defined as an internal process that can initiate, guide and sustain human behaviour over time, and it can have many different sources, levels of intensity and purposes depending on the individual and context. It is considered a critical factor in understanding teaching and learning processes in schools (Slavin, 2006).

There are multiple theories on motivation. In *behavioural learning theory*, motivation is seen a consequence of reinforcement with behaviours that have been rewarded in the past more likely to reoccur than those that have been

ignored or punished (Schunk, 2012). However, motivation is complex and it is difficult to assume the motivational factor of an incentive as it may depend on many different factors. Although *behavioural learning theory* is more related to extrinsic motivation, it may be argued that the reward might be internal such as enjoyment or interest and thus intrinsic motivation could be occurring.

Another concept of motivation is that of satisfying needs. Maslow's *theory of human needs* (Maslow, 1998) is based on a hierarchy of needs where the growth needs originate from the needs for knowing, understanding, and appreciating. Attempts at satisfying these growth needs can only occur after more basic needs (or deficiency needs), such as those for physical and psychological welfare, are met. At the highest level of growth needs, is self-actualization which can be viewed as the reaching of one's potential. According to Maslow's theory, students who feel accepted and respected as individuals are more likely to be intrinsically motivated to learn.

Attribution theory focuses on explanations for success and failure in achievement situations. According to this theory, self-efficacy is an important factor in explaining success or failure. Students with high self-efficacy are more likely to believe that their efforts and abilities are reasons for their success and failures whereas those with low self-efficacy are more likely to contribute it to task difficulty and luck (Weiner, 1974).

Academic enjoyment

Accessibility of goals and emotions are important regulators of motivation (Hannula, 2006). According to Hannula, “emotions are the most direct link to motivation” (p.167). Ma (1997) substantiates this and adds that the feeling of enjoyment is more of a deciding factor for students than the feeling of difficulty. It is enjoyment that affects attitude which, in turn, affects academic achievement. By using art in mathematics classes, students who enjoy art can be taught mathematics by relating it to the art they wish to produce (Biller, 1995; Hanson, 2002; Hickman & Huckstep, 2003; Sendova & Grkovska, 2005).

Self-efficacy

As Bandura (1993) explains, “Efficacy beliefs influence how people feel, think, motivate themselves, and behave” (p.118). In particular, it is well known in mathematics that students with low self-efficacy beliefs are more prone to disengaging from the learning environment, and give up much more easily when they encounter difficulties. In comparison students with high self-efficacy beliefs are more likely to persevere and welcome challenges (Hahn, 2008; Johnson, 2009; Odom, 2010; Sakız, 2007, Schunk, 1991, Williams & Williams, 2010).

However this relationship may not always be straightforward as higher skills might mean that students do not need to persevere as long to solve a problem. Further research is needed to examine the complex relationship between sustained effort and self-efficacy beliefs in academic settings (Schunk, 1991).

Self-efficacy beliefs are concerned not with the skills the person has but with the belief of what they can do with those skills. As such, self-efficacy affects cognition,

motivation and thus achievement (Bandura, 1993; Hahn, 2008; Johnson, 2009; Odom, 2010). In short, it is almost impossible to explain phenomena such as motivation and performance without considering self-efficacy beliefs (Johnson, 2009).

In their review of research, drawing studies and data from 33 nations, Williams and Williams (2010) look deeper into self-efficacy as an influence on performance. They summarized their findings as “self-beliefs and performance iteratively modify each other until the individual comes to a realistic appraisal of his or her self-worth or competence relative to the (mathematics) tasks at hand” (p.463). They deemed it reasonable to suppose that this would occur by the age of 15. Another interesting conclusion they came to was that girls reported lower levels of self-efficacy with respect to mathematics than the boys.

Another study by Hahn (2008), on 162 seventh grade mathematics students, indicated that enjoyment and motivation were very important in achieving success and found that self-efficacy affected both motivation and success. Sakız (2007) also found that academic enjoyment was positively related to both self-efficacy and academic effort, and that self-efficacy beliefs were positively related to academic effort. Indeed, students’ experiences in classroom must aim to raise academic achievement while providing students with opportunities to gain confidence in their own abilities at the same time. This is particularly important in middle school as students’ self-efficacy beliefs can affect their options in high school and beyond (Johnson, 2009).

Academic effort

The *expectancy theory* of motivation holds that a person's effort to achieve is based on their estimation of their success and the value they place on it (Slavin, 2006).

Research shows that motivation is determined by students' experiences and expectations of success. In addition, their attitudes and beliefs about themselves, mathematics and learning are also factors (Hannula, 2006; Healy, 2004; Singh et al., 2002; Sorensen, 2006). Studies by both Sendova and Grkovska (2005) and Healy (2004) found that using art increased students' levels of confidence due to the creative aspect of making sense of mathematics. Studies focusing on the use of art-based mathematical activities indicate that students' motivation to bring their project to life increases their chance of success and may even drive them to tackle more difficult mathematics than first anticipated (Biller, 1995; Hanson, 2002; Hickman & Huckstep, 2003; Sendova & Grkovska, 2005). Therefore, student's academic effort affects their potential for success (Brahier, 2013).

Activities for the classroom

Resources are plentiful for the mathematics teacher who wishes to use art in their classroom. The Association for Teachers of Mathematics (www.atm.org.uk), based in the UK, and the National Council of Teachers of Mathematics (www.nctm.org), based in the USA, both produce journals which include articles about such activities. In addition, there are numerous books and articles which give further examples of how these works can be adapted to the classroom (e.g., Bier, 2010; Boles &

Newman, 1990; El-Said & Parman, 1976; Field, 1997; Harker, 2009; Kappraff, 1991; Mitchell, 2005; Murray, 1994; Sanders, 2003).

Summary

Healy (2004) writes, “mathematics produces, generates and inspires art while art engenders and illuminates mathematics” (p.4). Teaching mathematics through art is a viable option. It enables students to see how mathematics is used in the real world and also allows them to experience concepts visually whilst partaking in artistic processes that yield a product of which they can be proud.

Using art-inspired activities in mathematics creates a powerful learning experience and there is much research recording how it affects academic understanding and achievement. It is clear that enjoyment and interest are seen as necessary for motivation. However, there is little research about the effects of using art in mathematics with regard to enjoyment, interest and motivation. An exception is Shaffer’s study (1997) in which he refers to the excitement and positive attitudes of the students. Then again, a weekend voluntary workshop with high school students represents a different population and context from a middle school mathematics classroom. There also exists some research about increasing confidence levels but this, too, is not extensive.

It seems, therefore, that there is a need for further research examining how art affects change in students’ enjoyment, self-efficacy and academic effort in mathematics in middle school.

CHAPTER 3: METHOD

Introduction

The purpose of this study was to explore and understand how the used of art-based mathematical activities affects the motivation of grade 7 students in a private school in Turkey.

In most educational research, both qualitative and quantitative methodologies can play a complementary role to understand educational phenomena about teaching and learning of mathematics (Presmeg, 2009). Uncovering group trends and relationships through solely quantitative methods is often not enough. There is also a need to understand the “Why?” behind these trends.

Concerning research on self-efficacy for example, Schunk, (1991) states:

Self-efficacy researchers typically have employed quantitative methods using between-conditions comparisons in short-term studies. There is a need for data collected in other ways: longitudinal studies, case studies, and oral histories. Although such studies might include fewer subjects, they would yield rich data sources for examining the role self-efficacy plays in academic motivation. Self-efficacy assessments might be similarly broadened from reliance on numerical scales to include qualitative indexes: Subjects could describe how confident they feel about performing tasks in different situations (p. 226).

It is for these reasons, that this study used a case study approach, using multiple data sources.

Research design

Art-based activities were used in one lesson a week for a period of six weeks. Pre- and post-surveys were given before and after the six week period. The surveys measured students' academic enjoyment, self-efficacy and academic effort. Data were also collected during the six week period through focus group discussions about each activity. These discussions and the survey results highlighted the key informants who were then interviewed for further insight.

Case study

According to Davey (1991):

Case study methods involve an in-depth, longitudinal examination of a single instance or event. It is a systematic way of looking at what is happening, collecting data, analyzing information, and reporting the results. The product is a sharpened understanding of why the instance happened as it did, and what might be important to look at more extensively in future research (para. 1).

A case study may cover a range of research methods as it is essentially a detailed examination of a single individual, group, incident or community. In this research, one particular class of grade 7 students was under examination. Although case studies are usually associated with qualitative research, they need not be limited to them (Wiersma, 1995). As case studies explore details and meanings of experience, a case study seems to be the most appropriate method for obtaining deeper understanding of how and why grade 7 students at a private school in Turkey might be affected by the use of art-based mathematical activities.

Within this case study, three types of data collection methods were used.

Survey

Surveys are used extensively in research as they gather information about a group's attitudes, beliefs, behaviours or achievement. Survey research is broad in scope but consists of two main designs: cross-sectional and longitudinal (Gay, Mills, & Airasian, 2009). The longitudinal design consists of data collection over time and at specific points in time. Longitudinal surveys may be of short duration or may span a longer time period (Wiersma, 1995).

Focus group

A focus group may be thought of as a group interview where the purpose is to try and collect a shared understanding from the group. All individuals in the group should contribute and no one individual should be allowed to dominate (Gay et al., 2009). In this study, the grade 7 class is considered the focus group.

Interviews

Interviews are an alternative method of conducting a survey and provide "opportunity for in-depth probing, and elaboration and clarification of terms" (Wiersma, 1995, p. 196). As such, interviewing members of the class allowed for greater understanding of the effects of the intervention on certain individuals. Unstructured interviews are similar to free flowing conversation, whereas structured interviews are formal and have a set of specified questions that enable the same information to be collected from all interviewees (Gay et al., 2009). For the purpose of this study, there were set questions where the participants were probed further according to their responses. In other words, the interviews were semi-structured.

Context

The study took place at private school in Ankara, Turkey. Founded in 1993, it offers pre-K to 12 education. Although the majority of students are Turkish nationals, there is also a small minority of international students. The school is small in size with approximately 600 students in all. It is an International Baccalaureate world school which is authorized to offer the Primary Years Program in the elementary years and the Diploma program in grades 11-12. It has also been approved by the University of Cambridge International Examinations to offer the International General Certificate of Secondary Education program and courses in grades 9-10. There is more flexibility in the curriculum of the middle school grades than the high school, and the middle school mathematics program is currently modelled on the British national curriculum with some aspects of the Middle Years Program included. Recently, the school has become a Turkish Ministry school and as such also conforms to the requirements of the Turkish national curriculum.

Participants

The participants were one class of grade 7 students taught by the researcher. The class was of mixed ability and consisted of nine boys and seven girls with a mean age of 12 at the start of the 2011-2012 academic year. Of the class, eight were international students and eight were Turkish nationals. One Turkish national had had all her previous education in England. This class was particularly interesting because of the 16, five were new to the country and the school. This resulted in a class with a wide variety of backgrounds: cultural and educational.

All students participated in the activities, pre- and post-surveys and the focus group discussions. The number of students and the selection criteria for the students to be interviewed were not decided upon until after the surveys and focus group discussions were completed.

Instruments

The survey instrument used was a modified version of the *Perceived Classroom Environment Scale* (PCES, Sakız, 2007). The PCES has six subscales of which only three were used for the instrument in this study: the *academic enjoyment*, *academic self-efficacy* and *academic effort* subscales. The PCES was developed for use in middle school with respect to mathematics and was therefore thought well suited for this study. The *academic enjoyment subscale* has six items and measures students' enjoyment in the mathematics classroom. The *academic self-efficacy subscale* has eight items and measures students' beliefs in their academic ability to perform well in mathematics. The *perceived academic effort subscale* has five items measuring students' perceived extra energy and hard work in mathematics.

Cronbach's alpha coefficient for internal consistency reliability for all three subscales was above the criterion value .70 (.84, .94, and .91 respectively). The validity of each subscale was also assessed as well and correlations among items provided evidence for the convergent validity of each scale (the range of correlations were .35 - .63, .53 - .82, and .49 - .78 respectively).

The survey instrument used in this study consisted of two sections (see Appendix A). The first section was a Likert-type survey consisting of 19 items measuring

enjoyment, self-efficacy and effort. Each item consisted of a statement followed by options for response; “not at all true”, “a little true”, “somewhat true”, “mostly true” and “completely true”. The second section collected demographic data from the students. The survey instrument was piloted on three grade 7 students before being used in the study. Due to the success of the pilot, no changes were made to the survey instrument.

The focus group discussions were structured with four questions in total; one for each construct (see the first four questions in Appendix C for details). The interviews were semi structured around the six questions found in Appendix C.

Data collection and analysis procedures

To address the following three research questions, survey data were used.

- *How do art-based mathematical activities used in mathematics lessons affect grade 7 students with respect to their enjoyment of mathematics?*
- *How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their self-efficacy?*
- *How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their academic effort?*

Figure 9 shows the overall process of data collection.

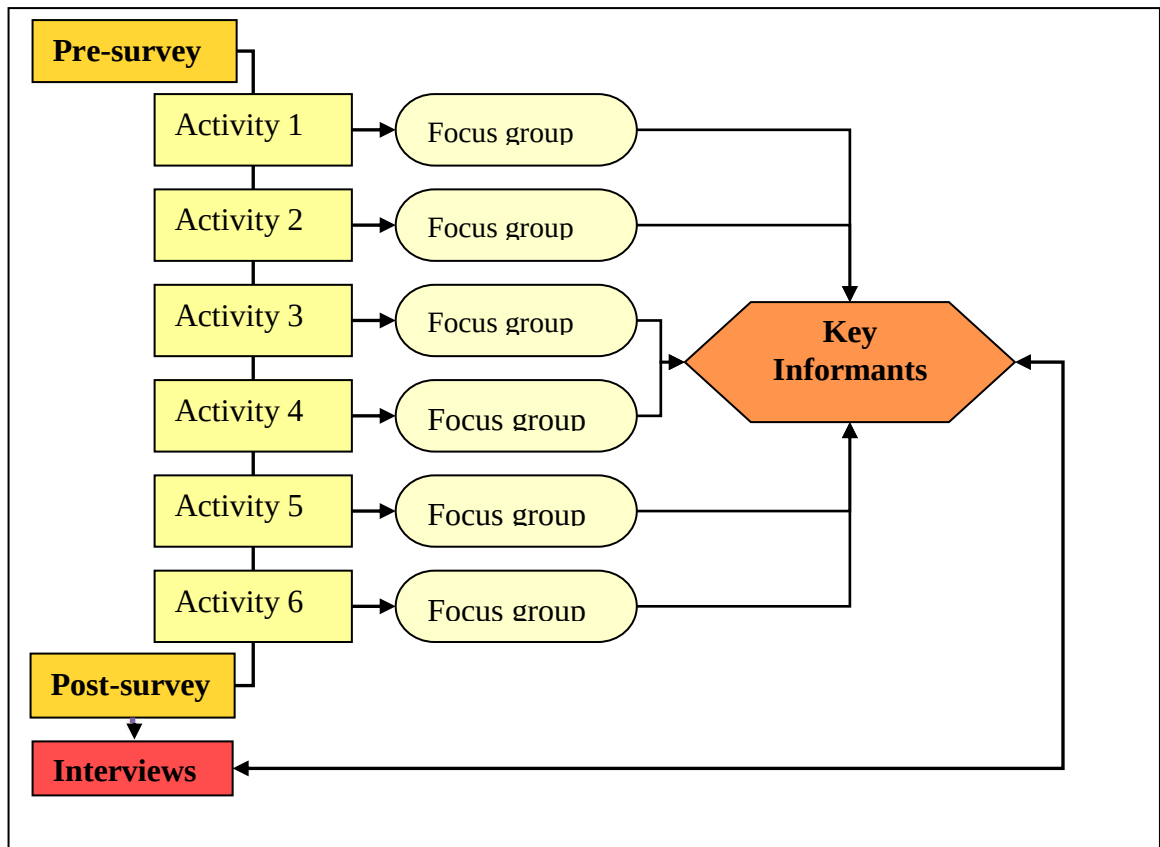


Figure 9. Flow chart showing process of data collection.

The survey was piloted on three grade 7 students who were not in the researcher's mathematics class and was found to be suitable for use. Before administering the pre-survey to the class, students were assigned numbers so that pre-surveys and post-surveys could be paired and analysed without bias. Students were asked to not write their names on the surveys but use their numbers instead. They were also provided with brief instructions on how to respond to the statements and were reminded about its confidentiality.

The pre-survey, focusing on academic effort, self-efficacy and academic enjoyment, was administered in class by the researcher in the first semester of the academic year, during the second week of October 2011. Following this, the activities began with the expectation of applying one a week for a period of six weeks (see Appendix B for activities). In reality, this took more than six weeks due to a school trip and other

unforeseen situations. However, all activities had been completed before the December holidays.

Each activity lasted for one 40 minute lesson with the first ten minutes of the following lesson being set aside for focus group discussions with the whole class. These discussions revolved around questions focusing on what the students liked about the tasks, why they felt that way, did they feel confident whilst doing it and were they motivated to complete their work. The discussions were recorded and the content was analysed for identifying recurring themes as well as possible key informants. Following the final activity and focus group discussion, the post-survey was administered to the class.

The pre-survey and post-survey were analysed looking at each of the three sets of items for the three constructs (academic enjoyment, self-efficacy and academic effort) separately. The results are reported with means, percentages and the chi-square test for goodness of fit. After the surveys had been analysed, the names of the students that have results of interest were uncovered. The key informants were identified through a combination of the findings from both the focus group discussions and the students highlighted from the surveys.

The key informants were then interviewed using a semi-structured interview (see Appendix C). A semi-structured interview was considered to be appropriate here as the study wishes to create a deeper understanding of how students are affected by the intervention. It was thought that structured questions may have been too limiting as the researcher may not have been aware of all the ways in which a student could

have been affected. Questions were built around academic enjoyment, self-efficacy, and academic effort and were, at times, influenced by recurring themes from the focus group discussions. The interviews were audio-recorded and the content was analysed in order to identify recurring themes and other interesting insights.

The other sub-question, *What are the beliefs of grade 7 students with respect to the nature of mathematics?*, was addressed in two stages. The first was during the focus group discussions with questions focusing on the perceived mathematical content of the completed activity. There were also questions built around this and students' definition of mathematics during the interviews. Analysis of data collected for this question was in the same form as above.

All data collection was completed by the end of March 2012.

CHAPTER 4: RESULTS

Introduction

Following the process of the study, the results are divided into two: quantitative and qualitative. Beginning with the quantitative, the survey analysis is reported by looking at each of the three constructs separately. The focus group discussions and interviews follow respectively. For ease of reading, the qualitative data is also reported according to the constructs.

Survey analysis

Academic enjoyment

The first research question was about the change in academic enjoyment of the students and was answered based on the data from the academic enjoyment subscale. The academic enjoyment subscale had six items. A five-point Likert-type scale (1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true) was used. All items were positively phrased. The data are summarised in Table 1.

Table 1
Summary of academic enjoyment subscale

item	pre-survey				post-survey		
	n	mean	SD		n	mean	SD
1.I get excited about going to this math class.	16	3.56	0.96		16	3.69	0.87
2.I enjoy participating in this math class.	16	4.25	0.86		16	4.25	0.93
3.I am looking forward to learning a lot in this math class.	16	4.44	0.89		16	4.31	1.08
4.It feels like time flies when I am in this math class.	16	3.38	1.20		16	3.25	1.29
5.I enjoy being in this math class.	16	4.25	0.86		16	4.25	0.86
6.After the class, I look forward to next math class.	16	3.44	1.15		16	3.81	1.22

Note: A five-point Likert type scale ((1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true)

The means for both the pre- and post-surveys indicate that students tended to have a positive approach to their enjoyment of mathematics, in particular with regards to items 2, 3 and 5. Furthermore, it indicates that students enjoyed mathematics both before and after the intervention.

The chi-square test of goodness of fit was applied to see if the change in scores for each item would be equally distributed. Figure 10 shows the null hypothesis (n=16).

H ₀ :	Change in pre- and post-survey scores (number of students)		
	Decrease	No Change	Increase
	$33\frac{1}{3}\%$ (5.33 items)	$33\frac{1}{3}\%$ (5.33 items)	$33\frac{1}{3}\%$ (5.33 items)

Figure 10. The null hypothesis for the chi-square test for goodness of fit.

The observed frequencies for the number of students whose score decreased, showed no change, and increased are given in Table 2 as are the results of the chi-square test.

Table 2
Observed frequencies for change, and chi-square values for academic enjoyment

Item	Observed Frequencies			χ^2	<i>p</i>
	Decrease	No change	Increase		
1	2	9	5	4.625	$p < 0.1$
2	4	7	5	0.875	
3	3	11	2	9.125	$p < 0.05$
4	3	11	2	9.125	$p < 0.05$
5	4	8	4	2.000	
6	4	4	8	2.000	

Note: n=16, df=2

Chi-square was significant for items 1, 3 and 4 showing distribution was not equal across all three categories. Inspection of the observed data for these items shows that the most crowded category was in the no-change group, and that most students were not affected by the activities with respect to their enjoyment of mathematics and their scores for these items showed no change.

A purpose of the survey was to help identify students for interviewing. To do this, the difference in the mean score of each student for the subscale was calculated and can be seen in Figure 11.

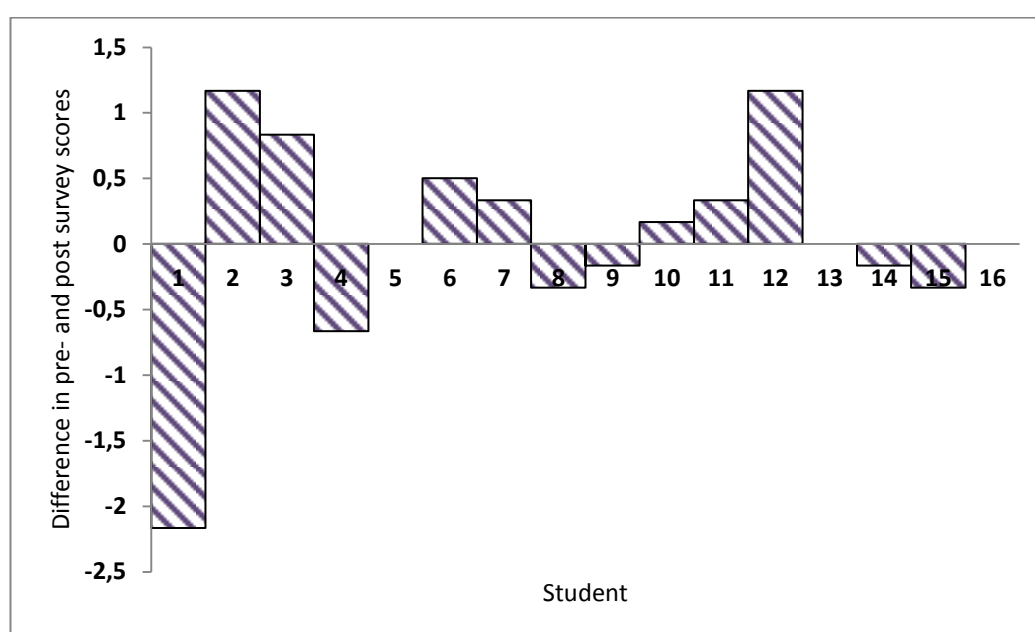


Figure 11. Change in mean score of students for the academic enjoyment subscale.

Students 1, 2, 3 and 12 appear to be most affected with regards to academic enjoyment.

Self-efficacy

The self-efficacy subscale had eight items. A five-point Likert-type scale (1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true) was used. All items were positively phrased. The data are summarised in Table 3.

Table 3
Summary of self-efficacy subscale

item	pre-survey			post survey		
	n	mean	SD	n	mean	SD
1.I believe I will receive an excellent grade in this math class.	16	3.69	0.60	16	3.69	0.60
2.I'm certain I can understand the most difficult mathematics presented in this class.	16	3.38	0.81	16	3.38	0.72
3.I'm confident that I can do an excellent job on the tests in this math class.	16	3.56	0.81	16	3.63	0.62
4.I'm confident I can understand the basic concepts taught in this math class.	16	4.56	0.51	16	4.31	0.70
5.I'm confident I can understand the most difficult math stuff presented by my teacher in this class.	16	3.63	0.81	16	3.75	0.93
6.I'm confident I can do an excellent job on the assignments in this math class.	16	4.13	0.62	16	4.13	0.62
7.I expect to do well in this math class.	16	4.44	0.63	16	4.50	0.63
8.Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.	16	4.00	0.73	16	4.31	0.60

Note: A five-point Likert type scale ((1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true)

The means for both the pre- and post-surveys indicate that students tended to have positive levels of self-efficacy, in particular with regards to items 4, 6, 7 and 8.

Furthermore, it indicates that students' levels of self-efficacy did not alter greatly after the intervention.

The chi-square test of goodness of fit was applied to see if the change in scores for each item would be equally distributed. The same null hypothesis as that for academic enjoyment was used (Figure 10).

The observed frequencies for the number of students whose score decreased, showed no change, and increased are given in Table 4 as are the results of the chi-square test.

Table 4
Observed frequencies for change, and chi-square values for self-efficacy

Item	Observed Frequencies			χ^2	<i>p</i>
	Decrease	No change	Increase		
1	3	10	3	6.125	<i>p</i> <0.05
2	3	10	3	6.125	<i>p</i> <0.05
3	3	8	5	2.375	
4	5	10	1	7.625	<i>p</i> <0.025
5	4	5	7	0.875	
6	4	9	3	3.875	
7	4	7	5	0.875	
8	3	6	7	1.625	

Note: n=16, df=2

Chi-square was significant for items 1, 2 and 4 showing distribution was not equal across all three categories. Inspection of the observed data for these items shows that, in all items, more students' responses resulted in the "no change" category as it was the most crowded out of the three. This implies that most students were not affected by the activities.

To aid in identifying the students to be interviewed, the difference in the mean score of each student for the subscale was calculated and can be seen in Figure 12.

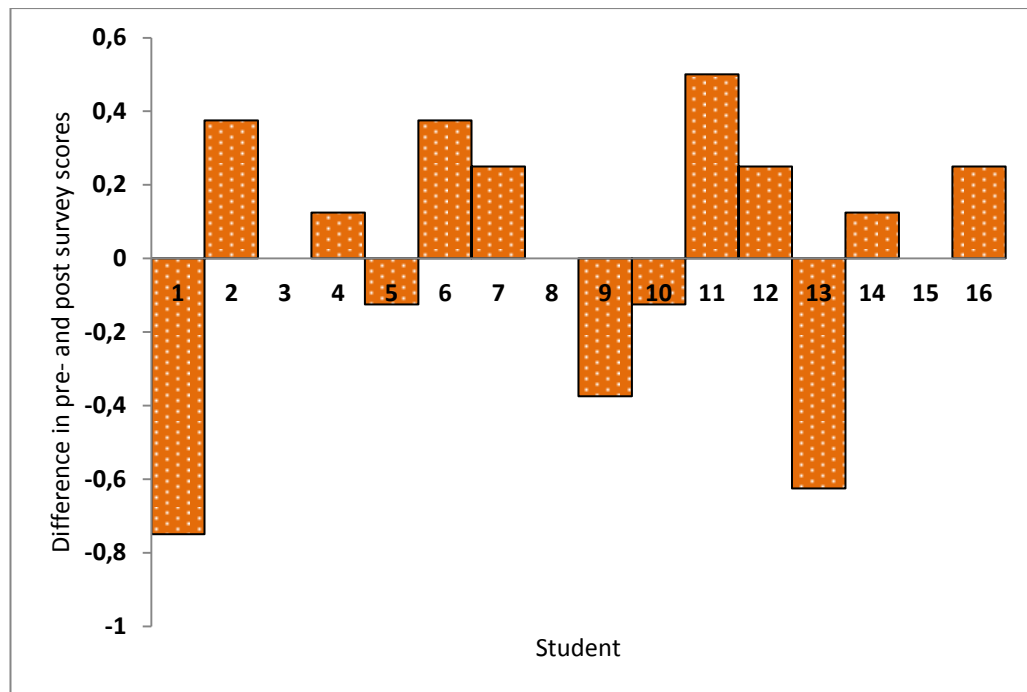


Figure 12. Change in mean score of students for the self-efficacy subscale.

Students 1, 2, 6, 9, 11 and 13 appear to be most affected with regards to self-efficacy.

Academic effort

The academic effort subscale had five items. A five-point Likert-type scale (1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true) was used. All items were positively phrased. The data are summarised in Table 5.

Table 5
Summary of academic effort subscale

item	pre-survey			post survey		
	n	mean	SD	n	mean	SD
1.I always work as hard as I can to finish my math assignments.	16	4.69	0.60	16	4.44	0.73
2.In math, even when concepts and materials are boring and uninteresting, I keep working until I finish my work.	16	4.19	0.66	16	3.75	1.24
3.I do everything I can to complete the given tasks in math.	16	4.44	0.51	16	4.31	0.70
4.I work hard to do well in math even if I don't like the content.	16	4.38	0.72	16	4.31	0.79
5.In math, I always put a lot of effort into doing my work.	16	4.25	0.86	16	4.06	0.85

Note: A five-point Likert type scale ((1=Not at all true, 2=A little true, 3=Somewhat true, 4=Mostly true, 5=Completely true)

The means for both the pre-survey and post-survey indicate that students reported that they put high levels of academic effort into their mathematics. Items 1, 3 and 4 had means that were particularly high. The table shows that students' reported levels of academic effort were high both before and after the intervention.

The chi-square test of goodness of fit was applied to see if the change in scores for each item would be equally distributed. The same the null hypothesis as that for the other two subscales was applied (Figure 10).

The observed frequencies for the number of students whose score decreased, showed no change, and increased are given in Table 6, as are the results of the chi-square test.

Table 6
Observed frequencies for change, and chi-square values for academic effort

Item	Observed Frequencies			χ^2	<i>p</i>
	Decrease	No change	Increase		
1	4	10	2	6.500	<i>p</i> <0.05
2	4	10	2	6.500	<i>p</i> <0.05
3	6	6	4	0.500	
4	5	7	4	0.875	
5	5	8	3	2.375	

Note: *n*=16, *df*=2

Chi-square was significant for items 1 and 2 showing distribution was not equal across all three categories. Inspection of the observed data for these items shows that

more students' responses indicated no change from pre- to post-survey for this construct and that most students were not affected by the activities.

The difference in the mean score of each student for the subscale was calculated and can be seen in Figure 13.

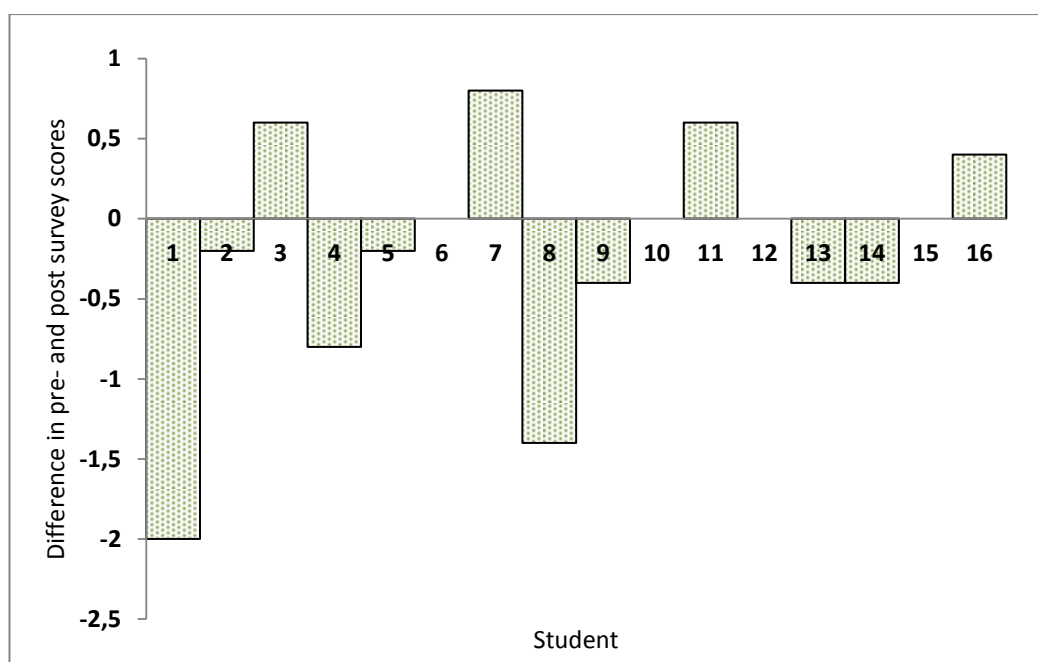


Figure 13. Change in mean score of students for the academic effort subscale.

Students 1, 3, 4, 7, 8 and 11 appear to be most affected with regards to academic effort.

Gender differences

Even though comparison between gender groups was not planned at the start of this study, there was evidence suggesting a difference between boys and girls. This study is primarily concerned with understanding how the intervention affects the students rather than who it affects. However, it is felt that it would be informative to draw

attention to the gender differences after data collection. The number of boys and girls did not suffice a chi-square analysis but the suggestive evidence is reported in Figure 14 which displays how the intervention affected the gender groups.

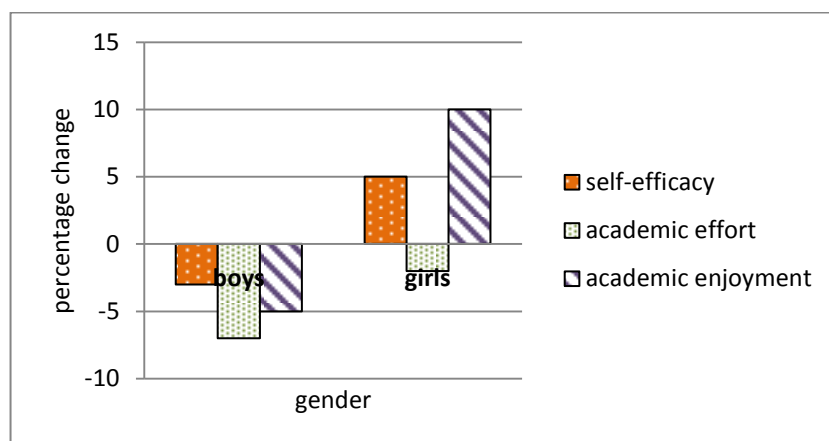


Figure 14. Overall percentage change in mean scores for gender groups.

Figure 14 shows that girls reported an increase in self-efficacy and academic enjoyment whereas the boys showed no improvement, but rather a decrease in the constructs.

Possible students for interviewing

A combined graph of the percentage change in the students mean scores for the subscales gives an overview of the way individuals were affected (Figure 15).

Possible students for interviewing are 1, 2, 3, 4, 7, 8, 11 and 12. These students were identified as their total change across the three subscales was above the 30% threshold.

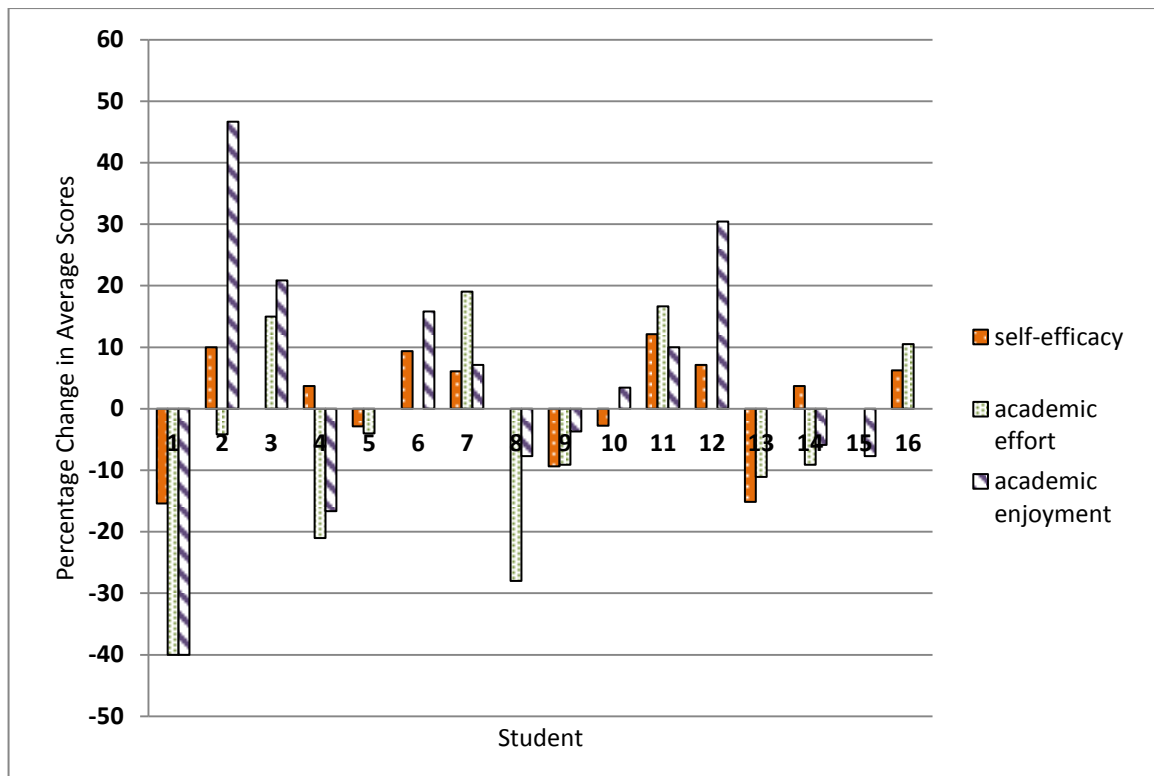


Figure 15. Percentage change in mean scores of individual students for all subscales.

Focus group responses

During the focus group discussions, students were asked for comments about their enjoyment, self-efficacy and academic effort. In addition, they were asked what mathematics there was in the activity. The six activities completed by the students were based on tessellations, origami, Islamic patterns, op-art, quilt patterns and animated snowflake (see Appendix B for activities). The discussions occurred after each activity.

Academic enjoyment

Students were asked whether or not they enjoyed the activity and to give reasons for their answer. The responses for the activities were as follows:

Tessellations

In this activity, students followed steps to design their own “Escher-like” tessellation. They used card to cut and form their own shape which they then tessellated on paper. Students mainly worked on their own, discussing the design of their shapes with peers if they wished.

[Positive]

- It was more fun than just doing an exercise from the text book on tessellations.
- It was new. I hadn’t heard of it before. It was fun and I loved the patterns made.
- I was surprised that translating could make this.
- It was new and interesting...better than text books.
- It was visual so it was less boring than our usual exercises.

[Negative]

- It was new but boring.

The majority of the students who commented about the tessellations activity reported positive feelings. The basis of their enjoyment was the visual beauty of tessellations; liking the patterns made by geometric transformations; and doing something unusual and different in the classroom.

Origami

Students followed a video showing instructions for the folds. After making a module each, students worked in pairs to make all the modules necessary for the shapes. The pairs then joined the modules to complete their shapes.

[Positive]

- Working with a partner was fun and challenging.
- Doing something physical rather than abstract was good.
- Knowing you'd get a good shape at the end was good.
- It was challenging. Physically folding paper and working with paper was difficult but good.
- It was challenging and had an element of complexity to it. It needed many parts to make the final thing which was cool so it tempted you to make it.
- It was fun and more difficult than other origami done in art and shapes were different.
- I enjoyed it because it was a new type of structure.

Students' comments about the origami activity were positive as they found it challenging, complex, and enjoyable to make something concrete on their own.

Islamic patterns

The students worked in pairs to analyse the Islamic patterns and decide on the constructions necessary to make them. Students then worked individually with compasses and rulers to construct the template shapes on tracing paper. They then traced the templates on another paper to form the Islamic patterns.

[Positive]

- I really liked the hands on stuff. It had many different components instead of just one.
- I enjoyed making the template because it was fun making the lines as well as making the figures.

- Making the template was good.
- I enjoyed colouring mostly but also enjoyed drawing the shapes.
- I enjoyed all of it. I liked the shape, the shape is really cool. I liked making the patterns with the compass.

All comments made were positive. Working with construction equipment and making the template were the main reasons given for their enjoyment.

Op-art

The class was shown various examples of op-art and the methods used were discussed as a class. Students worked individually using pencil, ruler and paper to create their own designs.

[Positive]

- I like art so doing it in math is fun.
- It was fun seeing the shapes change differently as I coloured them.
- I enjoyed seeing examples of op-art but not doing it myself.
- I liked it because we weren't calculators. We just needed rulers.
- I enjoyed seeing how lines could make something look 3D. It showed you that maths is not always numbers and that things you don't expect to be a part of maths is in it.
- It was interesting to see. Drawing your own creation was fun.

[Negative]

- I couldn't do it so I didn't enjoy it.

The majority of the students who commented reported positive feelings for the op-art activity. They liked doing mathematics without numerical calculations; making 3D pictures using only parallel lines and found it fun and interesting.

Quilt patterns

This activity allowed students to use paper, scissors and colours to create different designs using rotation.

[Positive]

- I enjoyed it because it was hands on and relaxing. A break from quizzes and tests.
- It was cool seeing all the different designs.
- I enjoyed it because it gave us a break from doing projects.
- I love colouring and like learning about patterns and art.
- I liked it because it was easy. You don't need to use your brain much but it teaches you about symmetry.
- I enjoyed it because it was new for me and I learnt something.

[Negative]

- I didn't like it because I don't like colouring. It would have been better if it was smaller so that we had less colouring.

The majority of the students who commented reported positive feelings for the quilt patterns activity. They found it relaxing and easy, whilst being informative.

Animated snowflake

Technology was needed for this activity and students brought their own laptops to work on. Unfortunately, some students forgot to bring their laptops so they ended up having to pair up with those that did.

[Positive]

- It was neat to make an animation that was still geometrical.
- I liked it because it was animated.
- It was great to animate.

[Negative]

- I had to do it quickly, if we could explore it more it would have been better.
- We had little time that's why we couldn't understand and do the construction quickly.
- I liked the program but the activity was kind of boring. The shapes looked the same.
- I didn't enjoy it because I wasn't involved. I was just watching.

Students had mixed feelings about this activity. Lack of time and access to technology were the main reasons for the lack of enjoyment. Those that did enjoy the activity gave the ability to animate their geometric shapes as the main reason.

As can be seen from above, most of the responses were positive with regards to enjoyment although reasons for it varied with respect to the student and activity. For example, during the snowflake activity, problems were encountered with technology which caused limitations with time and access to the software used.

Self-efficacy

The age of the students in the sample and their lack of comprehension of the word self-efficacy resulted in questions being re-phrased with the words confidence and belief in themselves to complete the task. Students were asked whether or not they felt confident during the activity and to give reasons for their answer. They were asked also if they found it easy and whether or not they believed they could do it.

The responses for the activities were as follows:

Tessellations

- It was complicated but not hard.

Origami

- I was not confident at the beginning but it made sense later.
- It was confusing because of all the flaps.
- It made my brain hurt.
- I was confident at first but not later as I had difficulty putting the pieces together.

Islamic patterns

- I started off not sure but felt confident when we got on to the tracing.
- At first I felt confident but not later.

Op-art

- I tried many times but couldn't succeed.

- It was frustrating. I had trouble drawing the parallel lines even though it looked easy.
- I found it frustrating as mine was not as good as the examples shown but I could still make it look 3D so I felt good.
- It was easy but the ruler sliding made drawing the parallel lines difficult.
- Sometimes it was difficult deciding whether to colour a part black or white.

Quilt patterns

- I didn't feel very confident because it was new to me.

Animated snowflake

- It was frustrating because we had little time.
- I would have liked to have explored it (Geometer's Sketchpad) before starting.

Students were not as forthcoming with their remarks as they were for enjoyment.

Responses were not categorized as positive or negative because some started off as one and ended as the other. The comments made by students generally expressed their frustration and lack of confidence in carrying out the activities. These reported feelings were about the art-based activities and were not about mathematics in general.

Academic effort

Students were asked whether or not they put effort into the activity and to give reasons for their answer. The responses for the activities were as follows:

Tessellations

[Positive]

- Yes, because I enjoyed it.
- I tried hard because I liked the patterns made.
- I put a lot of effort into it because it was new and interesting.

[Negative]

- No, because I found it boring.

Origami

[Positive]

- I worked the same as normal but that's a lot because that's what I always do.
- I was trying to work fast because I wanted to finish it.
- I put lots of effort in because I had to be careful and accurate and work quickly. Some of us even stayed back in the break despite having a test to go to.

Islamic patterns

[Positive]

- It was challenging but worth the effort.

Op-art

[Positive]

- I put more effort in than usual because the examples inspired me.
- I put more effort in because I was curious to see what will come out.

- I put more effort in because I wanted to do it correct. I tried to make it the same as the one shown.
- I put more effort in because I wanted to make an excellent one like in the examples.
- I put more effort in because it was interesting but there was no one answer. It was an answer from the heart...no right or wrong.
- I put more effort in because it was more interesting than just finding an answer. There was more creativity. It was about finding a balance between accuracy and creativity.
- I gave more effort on parallel lines than inside because that was more important.

Quilt patterns

[Positive]

- It was easy.
- I tried hard because it was cool to see the designs.
- I worked hard because I enjoyed it.

Animated snowflake

[Positive]

- I put effort in so that I could finish it.
- I had to work very quickly.
- I tried hard because I wanted to animate it.

[Negative]

- No, because I was just watching.

- I was helping my friend on her computer so after a while I just gave up.

As can be seen above, students were not as responsive to the question about self-efficacy as for the question about enjoyment, although some activities generated more responses than others. Generally, the comments made were rather positive and mentioned that they put in more effort because the activities were interesting, “cool”, inspiring and creative.

Mathematical content

Students were asked to state what they believed to be the mathematical content of each activity. Their responses can be seen in Table 7.

Table 7 shows that the students’ perceptions were very close to the actual mathematical content of all the activities, except for the origami activity. In the origami activity the discrepancy probably resulted from the students responding with a general “geometry” rather than breaking it down into sub-topics. Overall, Table 7 shows that students were able to make mathematical connections with the art-based activities in this study.

Table 7

The perceived and actual mathematical content of the art-based mathematical activities

Activity	Perceived Content	Actual Content
Tessellations	Translation Tessellation	Translation Tessellation
Origami	Geometry Angles Symmetry	Diagonals Angles Bisectors Midpoints Isosceles triangles Parallelograms Squares
Islamic Patterns	Geometry Angles Using compass and ruler to construct perpendicular lines and angle bisectors.	Angles Construction of perpendicular lines, squares and angle bisectors.
Op-Art	Angles Drawing parallel and perpendicular lines.	Parallel and perpendicular lines Rectangles
Quilt Patterns	Rotation Symmetry Shapes Angles in triangles	Rotation Symmetry Squares Triangles Fractions
Animated Snowflake	Geometry Shapes Symmetry Reflection Perpendicular lines Angle Bisectors	Polygons Reflection Symmetry Perpendicular lines Angle bisectors

Student interviews

Five students were selected for interviews. These students were chosen from among those listed in Figure 14 earlier, as a result of the survey analysis and their comments during the focus group discussions. The students varied in mathematical ability level, gender, nationality, and whether or not they were new students. For the sake of anonymity, the names given are pseudonyms.

Ashram – Student 1.

Ashram is an international student in his second year at the school. He is extremely good at computational work and is analytic in his thinking. He dislikes open-ended investigations, preferring to solve exercises from his textbook. His favourite lessons are mathematics and science. He was selected for interviewing because out of the whole class, he had the greatest percentage decrease in his average scores for academic enjoyment (-45%), self-efficacy (-15%) and academic effort (-40%).

Derin – Student 2.

Derin is a borderline student whose test marks in mathematics are below the 70% pass rate but whose homework and project grades enable her to just pass the year. She is a Turkish national and has been in the school for many years. Her favourite subjects are drama, social studies, art and English. She is not a very articulate student. However, she was chosen because out of the whole class, she showed the highest percentage change in her average score for academic enjoyment (47%).

Andrew – Student 3.

Andrew is a new international student to the school. His mathematical skills are weak and he is struggling to keep up although his effort is always at a maximum. He lists his favourite subjects as science, mathematics, social studies and drama. One of the reasons for choosing Andrew was that, out of the boys, he showed the highest percentage change in his average score for academic enjoyment (21%) and academic effort (15%).

Eda – Student 7.

Eda is a new student to the school. She is a Turkish national but has had all of her previous education in England. She is an able student but usually makes careless errors in her tests. Her favourite subjects are English, mathematics and science. She was selected for interviewing because out of the whole class, she showed the highest percentage change in her average score for academic effort (19%). Eda was also particularly articulate during the focus group discussions.

Melissa – Student 12.

Melissa is an international student who has been at the school for the last five years. She is one of the better students and is used to getting good grades. Melissa always tries her hardest and her scores in the pre-survey and post-survey for all the items in the academic effort subscale are 5. Her favourite subjects are English, science and mathematics. She was selected for interviewing because she was particularly articulate in the discussions and, out of the whole class, she showed the second highest percentage change in her average score for academic enjoyment (30%).

Academic enjoyment

Derin stated that she enjoyed the art-based activities because she is good at art. She found it interesting and was pleased to see that activities that looked difficult to start with, were in fact possible to do. “I never thought I could do the origami stuff. It looked complicated but I could do it.” She thinks that there should be more overlap between mathematics and art “because I don’t like lots of working out, numbers and stuff. This was more interesting”.

Andrew enjoyed the activities because they were different. “Instead of doing problems, we get to know how to do stuff, like how to bisect angles.” Because he likes art, he understood it and therefore liked it. He thinks that art and mathematics can be combined. “More activities would be more fun. I enjoyed it and learned a lot as well.” He was particularly interested in the construction (ruler and compass) work. “All the activities were nice but I liked the compass one. The design was good. You can mess with the shapes to get a design. Instead of working in a book, instead of having your pencil, writing questions and answering them, I like having a break and actually experimenting. It was fun and creative.”

Eda was quick to point out that she didn’t enjoy all of the activities equally. “Some activities depend on patience and other things I’m not good at.” Learning about how to make a tessellation tile and how to fit the tiles together was a lot more interesting for her than the origami. “I always wondered how tessellations worked. They are really interesting because they are creative. When you find out the maths behind it, you find out they’re not as complicated as they look.” Eda found the origami frustrating. It needed more patience and there were times when she had to redo

pieces because she had made mistakes. The fact that there were so many pieces also made it her least liked activity. The snowflake activity was also very interesting for her because of the software used. “I never knew you could do maths like that on a computer. I always knew about calculators on computers but I didn’t know about geometry based things on computers”.

Eda explained that she is good at art. “I’m better at the drawing and shading part than painting.” However she doesn’t find her art lessons very creative saying it is more about copying a picture and getting the shading right. “It’s nicer to have a finished product than a copy of a picture, something completely new.” In tessellations, “from a rectangle piece of paper you can have a whole new picture”. In the art-based activities she found out about the mathematics behind the art. She added that she learnt why things happen, why they work. “In origami, folding it right means the proportions are right and so it works.”

Melissa began by making general comments about the whole class. “I think that people really enjoyed it and that it inspired people.” She loved the activities. “They were really fun. You can see the math in them and see how it is related to art. I found them most interesting because I like things that are challenging.” The activity she didn’t enjoy was snowflake patterns because she felt frustrated when the technology didn’t work. “When I get frustrated, I’m not interested.”

Ashram didn’t enjoy the activities very much. “Some were okay, like the tessellations and origami but most were boring. The origami was good because it was challenging and I enjoyed working with paper, folding it and stuff.” He adds that he

had difficulty with some of the skills, such as using compasses and drawing parallel lines and he didn't enjoy the activities that involved them.

Overall, most of the interviewed students reported that they enjoyed the activities because they incorporated a different style of work and learning than their usual mathematics lessons. They enjoyed the opportunity to be creative and liked having hands-on experiences and using equipment that varied from that usually associated with mathematics lessons such as compasses, rulers and technology. These students varied in mathematical ability but were generally students who enjoyed art. Students seemed to dislike activities that needed skills that were difficult for them. Ashram was one such student. His fine motor skills were not very good and this made some tasks very difficult, sometimes resulting in his giving up altogether.

Self-efficacy

Andrew explained that he felt more confident doing art-based mathematical activities because he could find his own way of doing things. He could be more creative. "Using art-based activities made it easier".

Ashram felt confident during the activities he could do, such as the tessellation. "It was easy to end up with a shape that tessellated". However, working with compasses caused problems. "I'm not used to that type of stuff. Usually, I'm the first to finish an exercise in class, but with this work I wasn't as fast."

Melissa believes that “some activities may improve confidence but math-art is different to numerical math. It might inspire kids to do better mathematics because it helps them realise that there is more to math than just numbers on a page”.

Eda believes that mathematics is everywhere and teachers need to find ways to motivate students. “If students don’t enjoy maths, they usually enjoy art and it’s a psychological thing.” Eda believes that students are either better at mathematics or creative work. She feels strongly that teachers should try to motivate students in mathematics and “should show things like equations, geometry, etc. can also go in design technology, art, even science”.

To summarise, most of the students interviewed believed that self-efficacy did increase with the use of art-based activities. They felt that by using art-based activities in class, mathematics could be made more accessible and could bring more confidence to those who had previously not felt so. Once again, Ashram did not feel in quite the same way as the others. He felt distressed at not being as successful as he had been in mathematics classes before the intervention. The fact that he had difficulties and was no longer the first to finish in class affected his self-efficacy negatively.

Academic effort

Most students answered questions about effort briefly saying that they always put effort into their work. Derin commented that “as a student, I never give up so I tried as hard as I always do”. Melissa explained “I would complete them at home if I didn’t complete them at school”.

Ashram explained that with the origami he worked as hard as he usually did. However, with some of the other activities, this was not the case. “The tessellation one was easy so I didn’t try very hard. I got a shape that tessellated and that was enough. I didn’t try to make a brilliant animal or anything.” There were other reasons for a decrease in effort. “I liked seeing the examples for the op-art but I couldn’t do it. I couldn’t draw the parallel lines so I gave up.”

The students interviewed tended to have very high levels of academic effort before the intervention and in most, they did not perceive any change with the use of art-based activities. Ashram appeared to be the student most adversely affected. He reported two reasons for this: either the work was too easy or it was too hard. His lack of artistic temperament meant that he was unwilling to work on improving a design. He was uninterested in creativity and aesthetics. He had a design that fulfilled the criteria and that was enough for him. Once he had achieved the basics, he stopped. When tasks became too difficult, due to his lack of fine motor skills, he once again did not persist and gave up altogether.

The nature of mathematics

Andrew started by saying “My teachers say it is a language. I say it kind of guides you in your daily life as you get older”. He explained further. “Math is all around us and we use it every day. You see shapes. They are made of numbers.” He adds that “numbers are more important”.

Derin used to think that mathematics was just numbers but now she sees that art is a part of it also. “Before the activities, I didn’t know that there was an art side also. I didn’t know it was this interesting.”

Eda was affected “quite a bit” by the experience. “I didn’t know that there was so much maths involved in art. Maths has a lot wider spread than I thought it had.”

Melissa spoke of how the activities were not “exact math”. She explained that what she meant by exact math was numerical mathematics, work with text books, notes, exercises, and so forth. She also thinks that mathematics is beautiful “because math is not just numbers on paper. Math is nature, art and buildings and I think math is very beautiful”. She explains that math is visual. “I see math. It looks beautiful to me because it is interesting and a different way of thinking. It is one language on its own.”

Ashram commented on how our activities did have mathematics in them but for him “it’s not real math. Math is really about numbers and algebra”.

Many of the interviewed students did have a wider scope of the nature of mathematics after the art-based activities. However, it is interesting to note that both Melissa and Ashram, two of the students with the highest grades in the class, referred to the mathematics in the activities as “not real” and “not exact”. For them, real and exact mathematics is the mathematics of their usual lessons, text books, tests and exams.

Other themes

Art-based activities as a learning tool

Andrew believed that art-based activities were not beneficial to everyone. “It depends on how you learn: if you like doing problems out of a book, or if you like art, like being creative.”

According to Melissa “the different type of math may have opened up people’s mind and inspired them to do better in their other math areas”. She thought tessellations were a good way to learn about translation because it is a “different format of learning. Instead of writing translation is this, people experimented with it. I think that experimenting is a powerful way of learning”. Overall, “art-based activities in math are good but it would make more sense if it was incorporated alongside lessons like geometry instead of statistics. It takes a lot of our lesson time and we were behind”.

Ashram also felt that the activities took a lot of time. “Working from the board and our text book is faster. We can cover the topics a lot more quickly that way.”

Creativity

Both Andrew and Eda referred to creativity when explaining why they enjoyed the activities. Andrew tried to explain that “math is creative. It explains lines and stuff. Numbers explain lines”. He went on to add that he could also be more creative and find his own ways of doing things.

According to Eda creativity is important in mathematics. She refers to the need for creativity when it comes to finding rules in algebraic investigations. Melissa also referred to the place of creativity in mathematics. She believes there is creativity in mathematics because there are “also creative ways to find a solution...not just one way to find a solution, many ways”.

CHAPTER 5: DISCUSSION

Introduction

The aim of the study was to explore and increase understanding of how the use of art-based mathematical activities affects the motivation of grade 7 students in mathematics lessons in a private school in Turkey.

The study addressed the following main research question:

1. How does the use of art-based mathematical activities affect the motivation of grade 7 mathematics students in a private school in Turkey?

The following sub-questions were used to address this main question.

- a. How do art-based mathematical activities used in mathematics lessons affect grade 7 students with respect to their enjoyment of mathematics?
- b. How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their self-efficacy?
- c. How do art-based mathematical activities used in mathematics lessons affect grade 7 students' beliefs with respect to their academic effort?
- d. What are the beliefs of grade 7 students with respect to their conception of the nature of mathematics?

Overview of the study

This study focused on how grade 7 students' conceptions of the nature of mathematics and their enjoyment, self-efficacy and academic effort were affected by using art-based mathematical activities in their mathematic lessons.

The statistical analysis of the quantitative data indicates that using such activities in the classroom gives rise to no significant change, positive or negative, on the three constraints: academic enjoyment, self-efficacy and academic effort towards mathematics in general.

It is to the group discussions and interviews that we must look for evidence of the effect of the intervention on individual students. Amongst this qualitative data, much evidence exists contrary to the statistical findings. Many positive comments were made about the activities and, in particular, students' heightened enjoyment. Comments regarding not wanting to leave the lesson and voluntarily staying behind during break were particularly indicative of students' level of enjoyment. Such comments were more often made by the girls in the class.

The interviews also highlighted that the students' conceptions of the nature of mathematics were affected by the intervention in that they began to realise the subject had a wider scope than formerly thought. The six art-based activities in the intervention challenged their view of mathematics and even gave rise to students talking about the beauty and creativity of mathematics.

Major findings

Academic enjoyment

This section refers to the first research sub-question, *How do art-based mathematical activities used in mathematics lessons affect grade 7 students with respect to their enjoyment of mathematics?*.

It seems that students enjoyed mathematics because they had high levels of academic enjoyment both before and after the intervention. However, having high levels of enjoyment before the intervention (with the pre-test means ranging from 3.38 to 4.44 for the six items), did not allow much room for improvement after the intervention. This might be interpreted as a ceiling effect in the measurement of this construct of this intervention study.

This level of enjoyment is also reflected in the 2007 TIMSS study where results showed that in Turkey, the percentage of students who stated that they completely agreed with the statement “I enjoy learning mathematics” was above the international mean (Bilican, Demirtaşlı, & Kilman, 2011). Similar findings exist in the 2003 Program for International Student Assessment (PISA) results. The percentage of Turkish students either agreeing or strongly agreeing with the statements “I look forward to my mathematics lessons” and “I do mathematics because I enjoy it” was twenty percent above the international mean (OECD, 2004).

Turning to the focus group discussions, comments made were mostly of a positive nature. Further, the atmosphere in the classroom during most of the activities was

positive. Comments like “I don’t want to leave your classroom” and “I definitely think that art makes people feel better about maths” made by Melissa and Eda respectively, seemed to reflect the general feeling in the room.

The individuals who appeared most affected with regards to academic enjoyment were chosen to be amongst those interviewed. The three who were positively affected gave reasons such as being good at art, finding it more interesting than working with numbers, and finding it challenging. Interestingly, the student who seemed to like the activity least was the most analytic student in the class. One of his reasons for not liking it was the difficulty he had with the skills necessary for the activities.

As stated by Brown, Brown, and Bibby (2008), two of “the most prevalent reasons for not continuing with Mathematics are the lack of enjoyment and that the subject is boring” (p.9). They suggest that a way to obtain a greater number of students electing to continue with mathematics would be to have more enjoyment and less boredom in the teaching of the subject in the lower grade levels. In particular, the qualitative data obtained from this study would suggest that using art-based activities in mathematics lessons would make the subject more enjoyable for some of the students.

Self-efficacy

Self-efficacy was the subject of the second research sub-question, *How do art-based mathematical activities used in mathematics lessons affect grade 7 students’ beliefs with respect to their self-efficacy?*.

Students appeared to have high levels of self-efficacy both before and after the intervention. Once again, these high levels before the intervention (with the pre-test means ranging from 3.38 to 4.56 for the six items) did not allow for much room for improvement after the intervention which might be interpreted as ceiling effect in the measurement of this construct.

Similar to enjoyment, this level of self-efficacy is also reflected in the 2007 TIMSS study where results showed that in Turkey, the percentage of students who stated that they completely agreed with the statement “I am good at mathematics” was above the international mean (Bilican, Demirtaşlı, & Kilman, 2011).

Comments made during the focus group discussions reflected the lack of confidence the students experienced during the activities. Some students started off confident and then lost that confidence later whilst others experienced the exact opposite. Many felt frustration because the activities, and the skills required, were so new to them.

One of the students most negatively affected by the activities was Ashram. He was particularly frustrated because he had always been the one to finish his work first in class but with these activities, this was no longer the case. Although, this may have had a negative effect on him, it is interesting to consider how it made other members of the class feel. Andrew, who would usually be one of the last to finish and who would have low self-efficacy, explained how his confidence grew during the activities because he could find his own way of doing things. Interestingly, Andrew’s pre-survey and post-survey scores showed no difference in his self-efficacy.

One reason for students' reported decline, or lack of increase, in self-efficacy in the surveys could be the timing of the post-survey. It was given a week before the final exam and there were several students whose quiz and test scores up until then had been failing scores. Yet during the discussions and interviews, some students referred to the increase in their self-efficacy when working on art-based activities. It may be possible that the activities were responsible for student's self-efficacy scores remaining the same, or decreasing less than would otherwise have occurred.

In general, the class had low averages on quizzes and tests during the period of the intervention. This is interesting because their reported level of self-efficacy was quite high. It is most likely that having the activities unrelated to the topics of the semester did not allow for a very accurate measurement of the change in students' self-efficacy with regards to the intervention. Grades are extremely important to students in Turkish private schools and many students' self-efficacy is directly related to their grades. Measuring self-efficacy in isolation may not have been possible in this study. Research indicates that girls have lower self-efficacy than boys in relation to mathematics (Brown et al., 2008; Louis & Mistele, 2012; Williams & Williams, 2010). In the quantitative comparison made by gender (see Figure 15), girls reported an increase in their self-efficacy after the intervention. These results suggest that this may be a possible area for further research.

Academic effort

The third research sub-question, related to academic effort, is considered in this section.

The scores for this construct in the pre-survey were high ranging from 4.19-4.69.

There was a slight decline in the post-survey scores but they still stayed reasonably high with a range from 3.75 to 4.44.

The majority of the comments made in the focus group discussions were positive with students saying that they had put a lot of effort into their work. They explained that they tried hard because the activities were inspiring, interesting and creative, and that they had wanted to finish them. Some of the students were so focused on finishing that they voluntarily stayed in class during their break in order to do so. However, it must be noted that students may have refrained from giving negative comments due to the fact that the researcher was their class teacher and they did not believe that she would stay neutral after hearing their negative comments.

All but one of the students interviewed had little to say on the matter of academic effort except that they always worked hard in mathematics. Ashram, once again the most negatively affected in the class, explained that his efforts decreased considerably because he gave up when he couldn't do it. Other times, he found it was easy to come up with a basic idea. He adds, "I didn't try to make it better or more creative because it worked anyway". When we consider Ashram's work on tessellations, this viewpoint becomes apparent. Ashram finished shape tessellates but it is crude and does not look much like an animal. As he states above, he was only interested in creating a shape that tessellated. He didn't care about the aesthetics of his shape. His interests did not lie in the beauty or creativity of his work but just the mechanics of whether or not the shape tessellated.

The nature of mathematics

The purpose of the final sub-question of this research was to understand the effect of art-based activities on students' outlook on mathematics and what, for them, constitutes mathematics. Students' perception about mathematics was not explored prior to the intervention. Instead, students were asked about the mathematical content of each activity and those interviewed were questioned further on the subject. It was found that the students' perception of the mathematical content of the activities was accurate. Therefore, it appears that the students were able to see the mathematics they were using even when it didn't appear to be the focus of the activity.

During the interviews, both Derin and Eda said that the activities had opened up their horizons and changed their perception of mathematics. Andrew also seemed to have been affected, referring to the interconnection of shapes and numbers. However, Andrew also commented on numbers being more important. In a similar way, Ashram said that the mathematics in the activities was not real mathematics. Mathematics, for him was about numbers and algebra. Melissa reflected the confusion within her perfectly. On one hand "exact math" is the type of work done in exercises in text books, whilst on the other, "mathematics is more than just numbers on paper...it is beautiful and visual".

Although it appears that for many students mathematics is really about numbers, algebra, and exercises from text books, it does seem as if doing art-based activities has opened-up a possibility to students of there being more to mathematics than formerly thought. This is apparent when Eda states, "maths has a lot wider spread

than I thought”. As Melissa says, “the different type of math may have opened up people’s mind and inspired them to do better in their other math areas”.

Implications for practice

The findings suggest several implications for teachers:

Multiple intelligence

Although, as a class, no significant change was observed with regard to students’ academic enjoyment, self-efficacy and academic effort toward mathematics in general, on an individual basis, there were students who reported that they experienced a considerable effect. Art-based mathematical activities involve a different learning and teaching style than that of the traditional mathematics classroom. Therefore, such activities can have varied effects on students. Some students totally dislike mathematics, or are unable to be successful at it. If these students are artistic and are motivated by art, then the use of art-based mathematical activities in their mathematics lessons may be a better way to inspire and motivate them. In contrast, it appears that students with analytical aptitudes may experience a decrease in motivation when art-based activities are used in the classroom. However, it may be argued that these students already have an appreciation for mathematics and thus the motivation for it.

It is far from this study’s intention to suggest the teaching of a particular area of content by only using art-based mathematical activities. Rather, these types of activities should be used to add to the range of instructional strategies a teacher has in order to allow for students’ different learning styles and their multiple

intelligences thus making the classroom a more equitable environment (Alagic, 2009; Hanson, 2002; Harker, 2009; Shaffer, 1997). After all, if a mathematics teacher only teaches from an analytical and symbolic perspective, then surely they are not making their subject accessible to all students.

Perception of mathematics

Although the study does not show a significant shift in students' beliefs about the nature of mathematics, individuals did report a difference in the way they perceived the subject. By incorporating art-based activities into the mathematics lesson, teachers can contribute to the development of students' perception of mathematics to include a more wide-ranging and non-stereotypical view of mathematics. By connecting art and mathematics, there is the opportunity to show that the holistic face of mathematics is more than just numbers and symbols. It allows students the chance to see the aesthetic beauty that mathematics can produce and that mathematics can offer more substantial interdisciplinary connections than mere data analysis.

Connecting cultures and the real world

Using art-based activities in mathematics lessons leads to a sharing of cultures and heritages. The activities in the intervention included references to the art and culture of the Japanese, Dutch, Islamic, and American amongst others. In fact, multicultural activities are abundant when we consider the mathematics and art overlap. After all, many believe mathematics to be the study of patterns. The world is full of patterns and each country has its own contribution. These range from Rangoli patterns in India, to African network patterns, to Celtic knots: all rich with mathematics.

There is much focus on making mathematics real, on connecting it to the real world. Integrating mathematics and art is a valid way of doing this. Exploring real mathematics in the patterns around us, allows all to make connections and understand mathematics in a different way.

Assessment

Activities need to be thought out carefully so as to be accessible to the students without being too difficult or too easy. Teachers need to be aware of the skills required for the activity, which may not usually be associated with the mathematics classroom and take these into account in the planning of their activities. These skills may be anything from drawing straight lines to folding paper and using scissors accurately. The activities should be integrated into the lessons so as to be taught with the relevant topic.

Studies have shown that the use of art in mathematics lessons does increase understanding (Hanson, 2002; Healy, 2004, Shaffer, 1997). Assessing the activities would allow for students who learn better in a less analytical way to achieve better grades and hence improve their self-efficacy (Williams & Williams, 2010).

Suggestions for further research

A study into the roles of gender, age, learning styles, and culture could prove fruitful and informative when considering who may gain most from the integration of art and mathematics with respect to motivation. This study showed that girls benefited more from the use of art-based activities than boys. Repeating the research with a much larger sample size would enable us to see if this is a common trend. It is of interest to

note that, according to PISA results, in many countries, including Turkey, males expressed a significantly higher enjoyment of mathematics than females (OECD, 2004). It would be interesting to see if integrating art and mathematics could increase female enjoyment of mathematics and hence point the way for teachers to create a more balanced way of promoting motivation and interest the subject.

The effect of assessment on self-efficacy with respect to art-based mathematical activities would be worth exploring. This would be of interest particularly if the study was carried out in a country like Turkey where grades are highly valued.

Finally, the students in the sample group had high scores for the three constructs: academic enjoyment, self-efficacy and academic effort both before and after the intervention. It would be worthwhile to see how the use of art-based mathematical activities would affect students in lower ability classes.

Limitations

There are several limitations to this study.

Firstly, this study is specific to one class of grade 7 students in a private school in Turkey and as such the results can only be generalised for a student population with similar background and grade level.

There was also only one teacher involved, the researcher herself, and the Hawthorne effect may have been responsible for students' positive attitudes and beliefs, due to

receiving attention from the teacher. The novelty of the activities may also have contributed to their enjoyment of the activities.

Due to the study's focus on intrinsic motivation, students' work on the activities were not assessed and nor was it related to any material on their quizzes, tests or exams. In fact, the mathematical topics covered by the activities were second semester topics and, as such, were unrelated to those that were assessed in the first semester. The self-efficacy subscale of the survey may not have been best suited for the study as two of the items referred to tests and text books, both of which were irrelevant to the activities. Also, the high scores on the surveys may have had a ceiling effect and made for difficulties in measuring the effects on the constructs.

A further limitation was the timing of the post-survey. There was a gap between the end of the intervention and the administration of the post-survey. Furthermore, the post-survey was given very close to the students' final exams, which is generally a high anxiety period.

REFERENCES

- Alagic, M. (2009). Guest editor's introduction. *Journal of Mathematics and the Arts*, 3(3), 117-118. doi:10.1080/17513470903226438
- Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, 28(2), 117-148. Retrieved from <http://ehis.ebscohost.com>.
- Bier, C. (2010). CarpetMath: Exploring mathematical aspects of Turkmen carpets. *Journal of Mathematics and the Arts*, 4(1), 29-47. doi:10.1080/17513470903149986
- Bilican, S., Demirtaşlı, R. N., & Kilmen, S. (2011). The attitudes and opinions of the students towards mathematics course: The comparison of TIMSS 1999 and TIMSS 2007. *Educational Sciences, Theory and Practice*, 11(3), 1277-1283.
- Biller, J. (1995, October). *Math in art or art in math*. Paper presented at the 9th Annual National Conference on Liberal Arts and Education of Artists, New York, NY. Retrieved from <http://eric.ed.gov/PDFS/ED405907.pdf>
- Boles, M. & Newman, R. (1990). *Universal patterns: The golden relationship: Art, math and nature* (Book 1 revised ed.). Bradford, MA: Pythagorean Press.
- Brahier, D. J. (2013). *Teaching secondary and middle school mathematics* (4th ed.). New Jersey: Pearson Education.
- Brown, M., Brown, P., & Bibby, T. (2008). "I would rather die": Reasons given by 16-year-olds for not continuing their study of mathematics. *Research in Mathematics Education*, 10(1), 3-18. doi:10.1080/14794800801915814
- Davey, L. (1991). The application of case study evaluations. *Practical Assessment, Research & Evaluation*, 2(9). Retrieved from <http://PAREonline.net/getvn.asp?v=2&n=9>

- El-Said, I. & Parman, A. (1976). *Geometric concepts in Islamic art*. CA: Dale Seymour Publications
- Emmer, E. (Ed.). (1994). *The visual mind: Art and mathematics*. Cambridge, MA: The MIT Press.
- Fellows, M. (1995). *The life and works of Escher*. UK: Parragon.
- Field, J. V. (1997). *The invention of infinity: Mathematics and art in the renaissance*. New York: Oxford University Press.
- Field, M., & Golubitsky, M. (1992). *Symmetry in chaos: A search for pattern in mathematics, art and nature*. Oxford, UK: Oxford University Press.
- Gay, L. R., Mills, G. E., & Airasian, P. (2009). *Educational research competencies for analysis and applications* (9th ed.). New Jersey: Pearson Education International.
- Hahn, A. E. (2008). Variables contributing to success in Algebra I: A structural equation model. (Doctoral dissertation). New Mexico State University. Retrieved from ProQuest Digital Dissertations database. (Publication No. AAT 3023470).
- Hannula, M. S. (2006). Motivation in mathematics: Goals reflected in emotions. *Educational Studies in Mathematics*, 63, 165-178.
doi:10.1007/s10649-005-9019-8
- Hanson, J. (2002). Improving student learning in mathematics and science through the integration of visual art. (Master's thesis). Saint Xavier University of Illinois. Retrieved from <http://eric.ed.gov/PDFS/ED465534.pdf>
- Harker, H. (2009). Group theory: Students' artistic visualisations. *Journal of Mathematics and the Arts*, 3(3), 119-122. doi:10.1080/17513470903177888

- Healy, G.H. (2004). *The effects of integrating visual art on middle school students' attitude toward mathematics*. (Master's thesis). University of Alaska, Anchorage. Retrieved from ProQuest Digital Dissertations database. (Document ID 790308291).
- Hickman, R., & Huckstep, P. (2003). Art and mathematics in education. *The Journal of Aesthetic Education*, 37(1), 1-12. doi:10.1353/jae.2003.0001
- Johnson, G.B.B. (2009). Developing a middle school survey of student engagement: Implications for closing mathematics achievement gaps. (Doctoral dissertation). University of South Carolina . Retrieved from ProQuest Digital Dissertations database. (Publication No. AAT 3354785).
- Kapraff, J. (1991). *Connections: The geometric bridge between art and science*. USA: McGraw-Hill.
- Louis, R. A., & Mistele, J. M. (2012). The differences in scores and self-efficacy by student gender in mathematics and science. *International Journal Of Science And Mathematics Education*, 10(5), 1163-1190.
- Ma, X. (1997). Reciprocal relationships between attitude toward mathematics and achievement in mathematics. *The Journal of Educational Research*, 90(4), 221-229. Retrieved from <http://ehis.ebscohost.com>
- Mann, E.L. (2005). Mathematical creativity and school mathematics: Indicators of mathematical creativity in middle school students. (Doctoral dissertation). University of Connecticut. Retrieved from ProQuest Digital Dissertations database. (Publication No. AAT 3205573).
- Maslow, A. H. (1998). A theory of human motivation. In C.L. Cooper & L. A. Pervin (Eds.), *Personality: Critical concepts in psychology* (pp.169-188). London, UK: Routledge.

- Mitchell, D. (2005). *Mathematical origami. Geometrical shapes by paper folding*. Herts., UK: Tarquin Publications.
- Murray, J. (1994). *Squares, patterns and quilts*. Derby, UK: Association of Teachers of Mathematics.
- NCTM. (2000). *Principals and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics. Retrieved from <http://www.nctm.org>
- OECD Program for International Student Assessment (2004). *PISA learning for tomorrow's world: First results from PISA 2003* (Vol. 659). OECD
- Odom, R. (2010). Cooperative learning: Middle school students' math perceptions. (Doctoral dissertation). Walden University. Retrieved from ProQuest Digital Dissertations database. (Publication No. AAT 3428146).
- Özdural, A. (2000). Mathematics and arts: Connections between theory and practice in the medieval Islamic world. *Historia Mathematica*, 27, 171-201. doi:10.1006/hmat.1999.2274
- Presmeg, N. (2009). Mathematics education research embracing arts and sciences. *Mathematics Education*, 41, 131-141. doi:10.1007/s11858-008-0136-6
- Sakiz, G. (2007). Does teacher affective support matter? An investigation of the relationship among perceived teacher affective support, sense of belonging, academic emotions, academic self-efficacy beliefs, and academic effort in middle school mathematics classrooms. (Doctoral dissertation). Ohio State University. Retrieved from ProQuest Digital Dissertations database. (Publication No. AAT 3262063).
- Sanders, C. V. (2003). *Geometric graphics. Design projects for geometry students*. CA: Key Curriculum Press.

- Schattschneider, D. (2004). *M.C. Escher: Visions of symmetry*. UK: Thames and Hudson.
- Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist*, 26(3), 207- 231.doi: 10.1207/s15326985ep2603&4_2
- Schunk, D. H. (2012). *Learning theories: An educational perspective* (6th ed.). Boston, MA: Pearson.
- Sendova, E., & Grkovska, S. (2005). Visual modeling as a motivation for studying mathematics and art. *Educational Media International*, 42(2), 173-180.
Retrieved from <http://ehis.ebscohost.com>
- Shaffer, D. W. (1997). Learning mathematics through design: The anatomy of Escher's world. *Journal of Mathematical Behaviour*, 16(2), 95-112.
Retrieved from <http://www.sciencedirect.com>
- Slavin, R. E. (2006). *Educational psychology: Theory and practice* (8th ed.). Boston, MA: Pearson Education.
- Singh, K., Granville, M. & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research*, 95(6), 323-332. Retrieved from <http://ehis.ebscohost.com>
- Sorensen, V. (2006). Motivating middle school mathematics students (Report on an action research project). Middle Institute University of Nebraska, Lincoln.
Retrieved from <http://scimath.unl.edu/MIM/files/research/SorensenV.pdf>
- Weiner, B. (Ed.). (1974). *Achievement, motivation and attribution theory*. New Jersey: General Learning Press.
- Wiersma, W. (1995). *Research methods in education: An introduction* (6th ed.). Massachusetts: Allyn and Bacon.

- Williams, T., & Williams, K. (2010). Self-efficacy and performance in mathematics: Reciprocal determinism in 33 nations. *Journal of Educational Psychology*, 102(2), 453-466. doi: 10.1037/a0017271
- Willingham, D. T. (2012). *When can you trust the experts: How to tell good science from bad in education*. CA: Jossey-Bass.

APPENDIX A: Survey

(Items for self-efficacy)

Directions: Here are some statements about your perception of math. On a scale of 1 to 5, where 1 is “not at all true” and 5 is “completely true,” please circle the number that indicates your opinion across each statement.

	Not At All True	A Little True	Somewhat True	Mostly True	Completely True
1. I believe I will receive an excellent grade in this math class.	1	2	3	4	5
2. I'm certain I can understand the most difficult mathematics presented in the text-books for this math class.	1	2	3	4	5
3. I am confident that I can do an excellent job on the tests in this math class.	1	2	3	4	5
4. I'm confident I can understand the basic concepts taught in this math class.	1	2	3	4	5
5. I'm confident I can understand the most difficult math stuff presented by my teacher in this class.	1	2	3	4	5
6. I'm confident I can do an excellent job on the assignments in this math class.	1	2	3	4	5
7. I expect to do well in this math class.	1	2	3	4	5
8. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.	1	2	3	4	5

(Items for academic effort)

Directions: On a scale of 1 to 5, where 1 is “not at all true” and 5 is “completely true,” please indicate your opinion about math by circling the most suitable number across each statement.

	Not At All True	A Little True	Somewhat True	Mostly True	Completely True
1. I always work as hard as I can to finish my math assignments.	1	2	3	4	5
2. In math, even when concepts and materials are boring and uninteresting, I keep working until I finish my work.	1	2	3	4	5
3. I do everything I can to complete the given tasks in math.	1	2	3	4	5
4. I work hard to do well in math even if I don't like the content.	1	2	3	4	5
5. In math, I always put a lot of effort into doing my work.	1	2	3	4	5

APPENDIX A: Survey (cont'd)

(Items for academic enjoyment)

Directions: On a scale of 1 to 5, where 1 is "not at all true" and 5 is "completely true," please indicate your feeling about math by circling the most suitable number across each statement.

	Not At All True	A Little True	Somewhat True	Mostly True	Completely True
1. I get excited about going to this math class.	1	2	3	4	5
2. I enjoy participating in this math class.	1	2	3	4	5
3. I am looking forward to learning a lot in this math class.	1	2	3	4	5
4. It feels like time flies when I am in this math class.	1	2	3	4	5
5. I enjoy being in this math class.	1	2	3	4	5
6. After the class I look forward to next math class.	1	2	3	4	5

A LITTLE BIT ABOUT YOU (a few more seconds...you are about to complete the survey 😊)

1. I am a ☐ Female ☐ Male (check one)

2. I am _____ years old.

3. My grade in mathematics at the end of last year was _____ (numerical or alphabetical value)

4.

If I were to rank the three school subjects I like the most (with #1 being the most favorite), they would be:

1-

2-

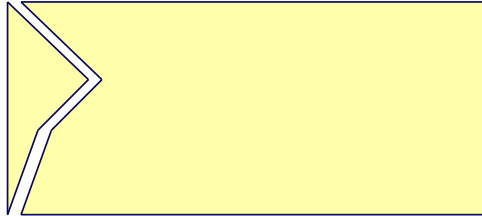
3-

THANK YOU VERY MUCH. WE TRULY APPRECIATE YOUR PARTICIPATION 😊

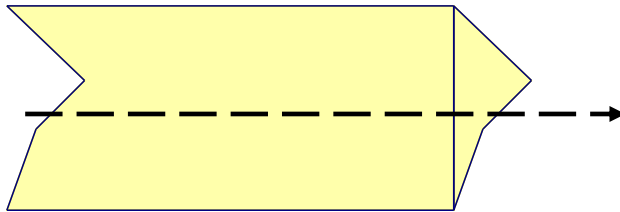
APPENDIX B: Activities

Creating Escher-like tessellations from card

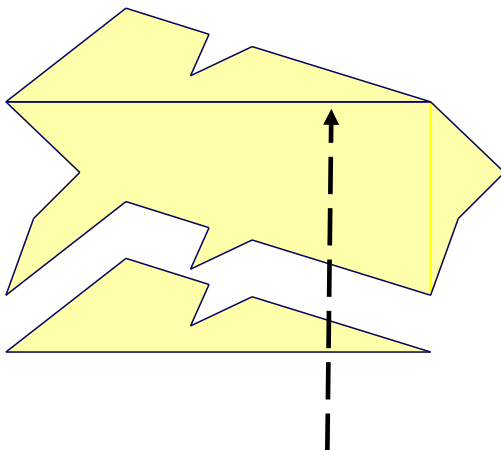
1. Start with a piece of rectangular card and cut a piece from one side as shown.



2. Slide (translate) the cut out piece to the opposite side and stick with tape.

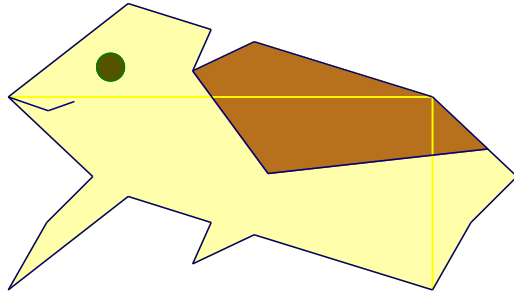


3. Cut a piece from the bottom side, slide (translate) it to the opposite side and stick with tape.

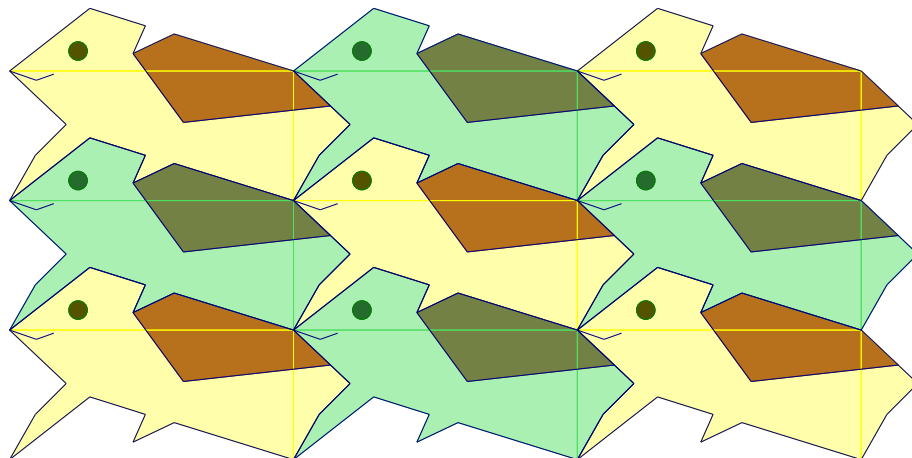


APPENDIX B: Activities (cont'd)

4. You now have a shape that you can tessellate. Look carefully at your shape to see what animal it looks like. (Some people might think this one looks like a turtle!)



5. Now put your cardboard shape onto paper and draw round it. Slide the shape across so that it fits exactly next to the one you have already drawn and drawn around it again so that you now have two shapes on your paper. Keep translating and drawing until your whole page is covered. Don't forget that shapes touching each other have to be different colours.

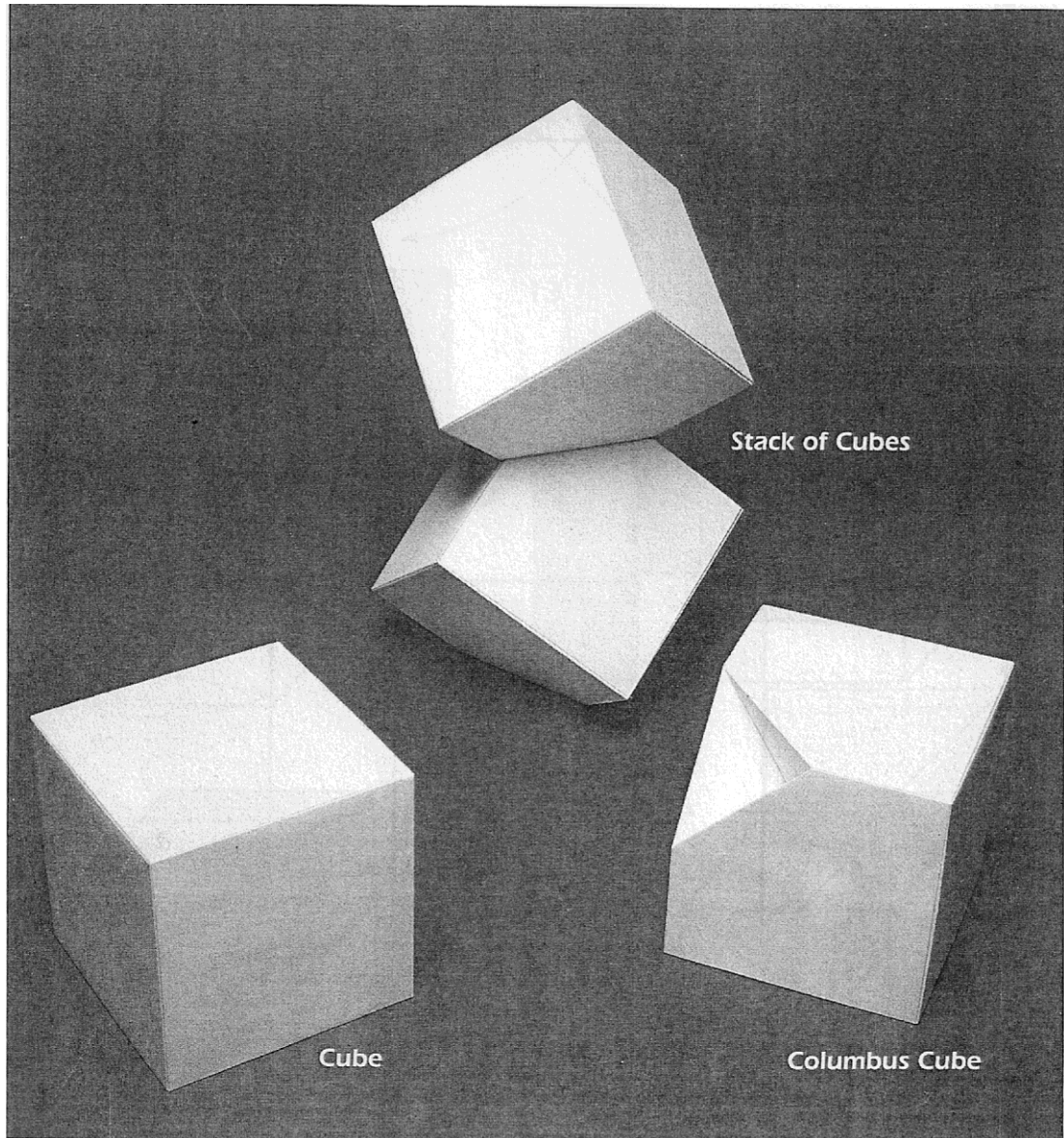


6. Now find a title for your work. This one is called "Tremendous Turtles".

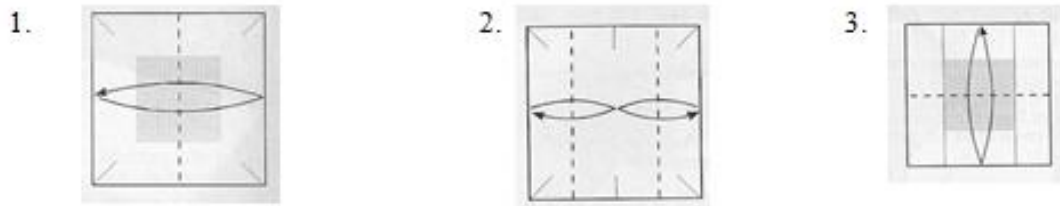
Congratulations you have completed your own Escher-like tessellation.

APPENDIX B: Activities (cont'd)

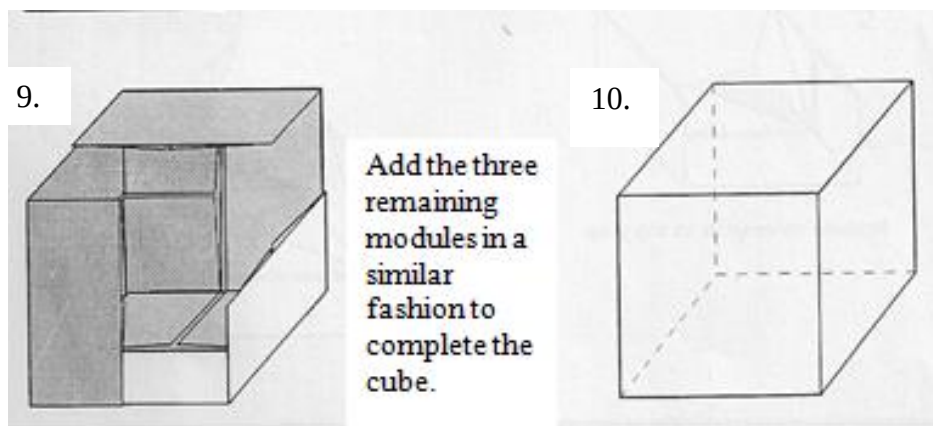
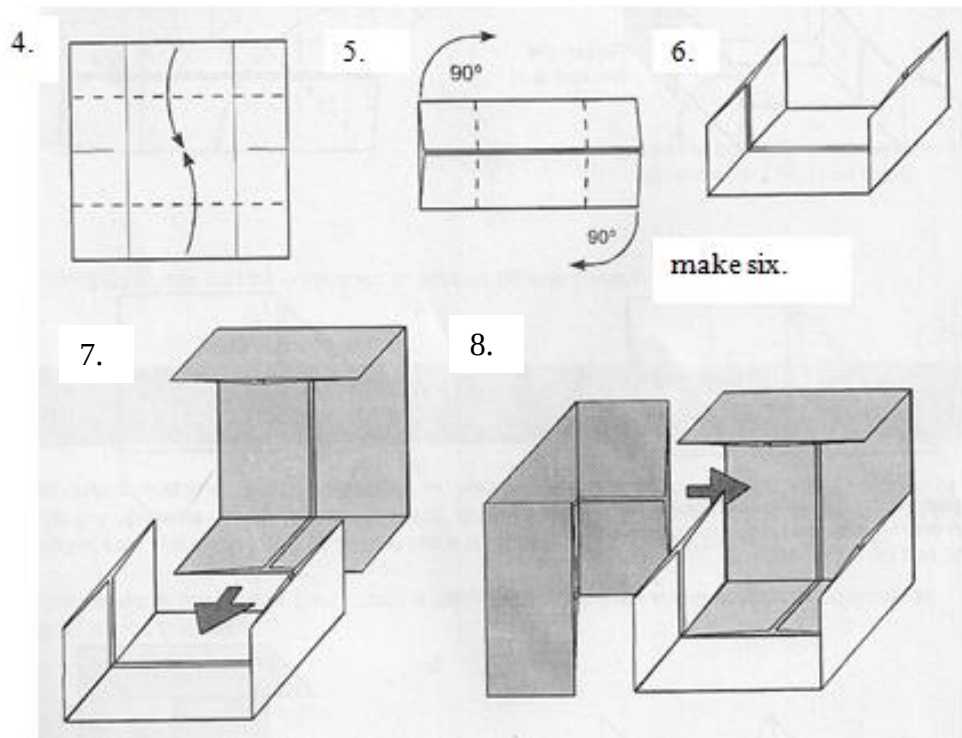
Columbus Cube (Origami)



APPENDIX B: Activities (cont'd)

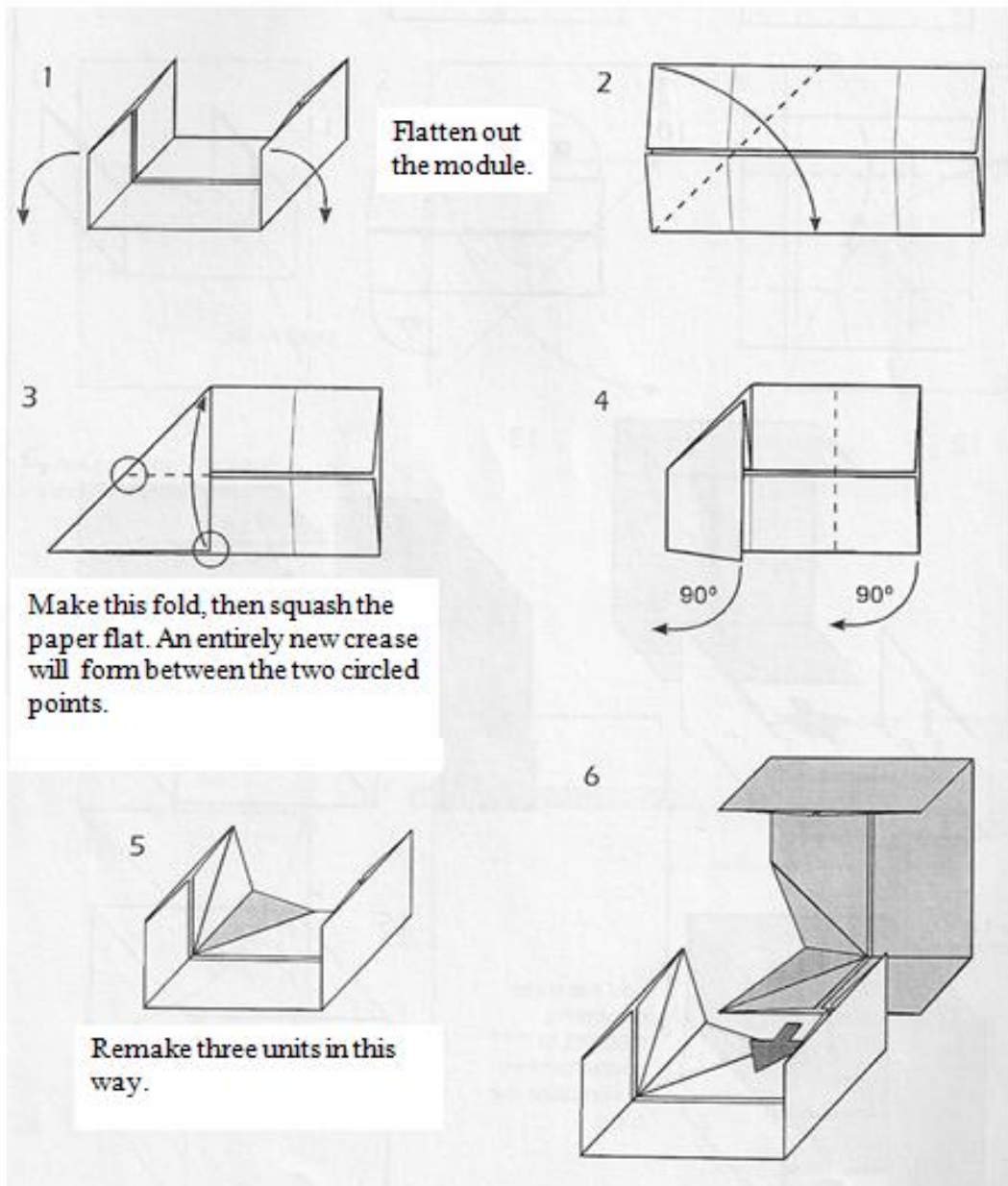


Try not to crease the paper inside the shaded area |

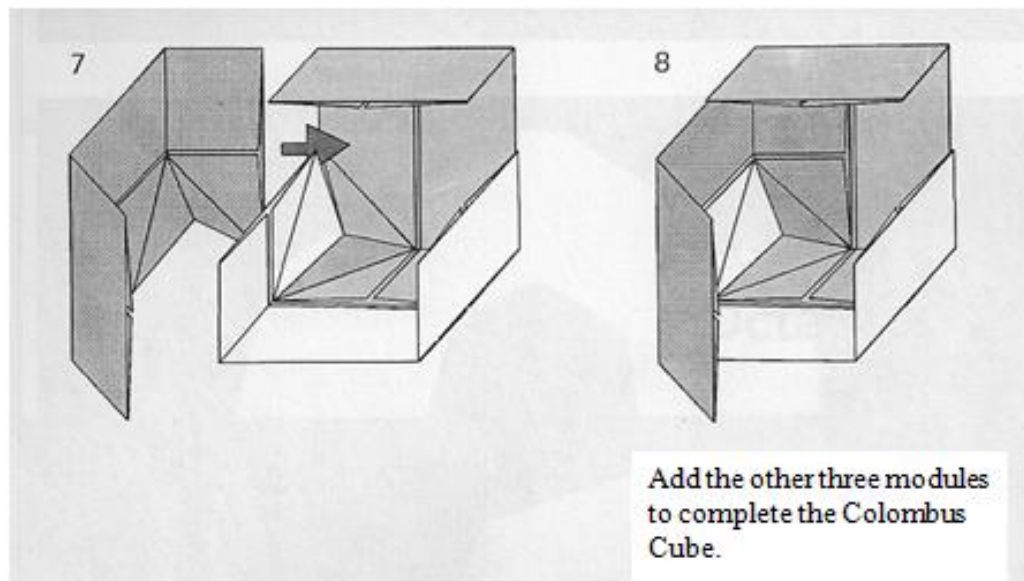


APPENDIX B: Activities (cont'd)

Now take your cube apart and alter three of the modules as shown.



APPENDIX B: Activities (cont'd)

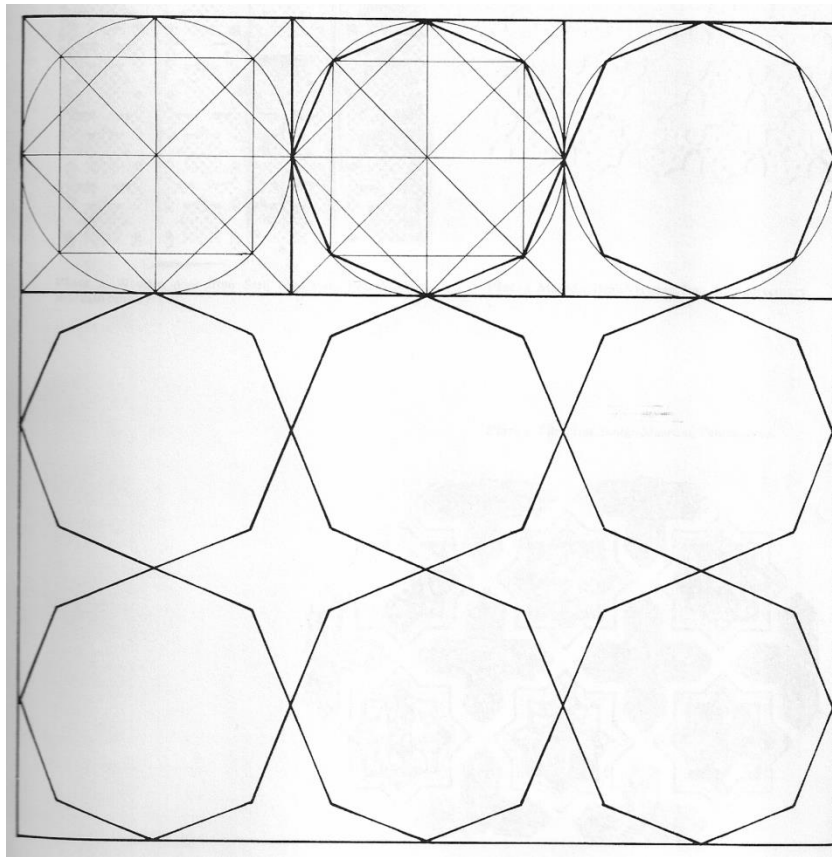


Columbus cubes can be combined in several different ways. How many ways can you think of?

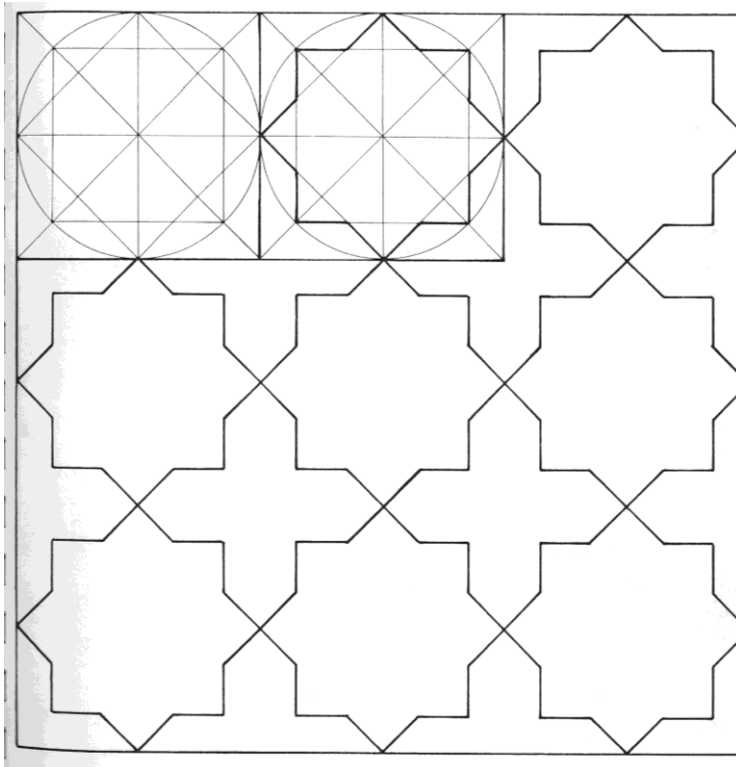
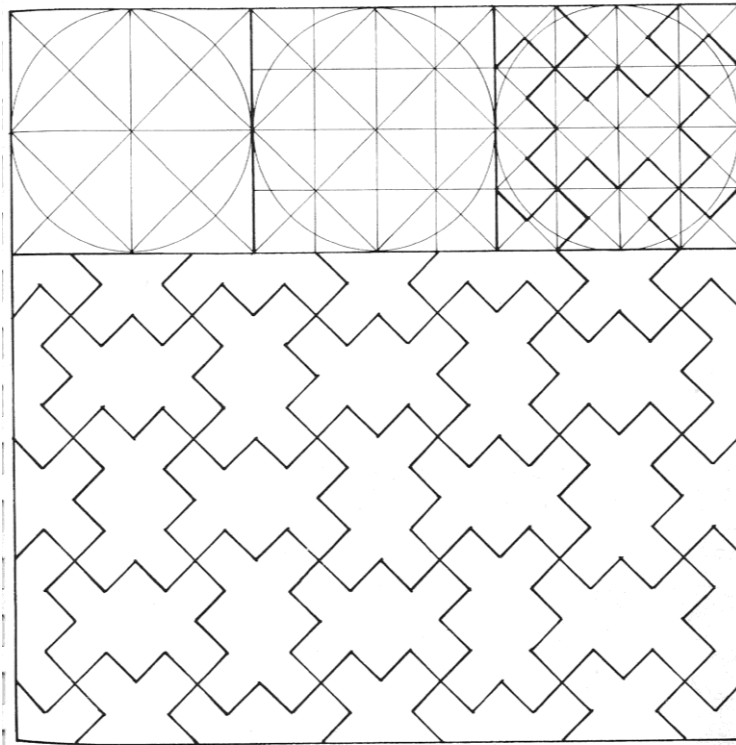
APPENDIX B: Activities (cont'd)

Islamic Patterns

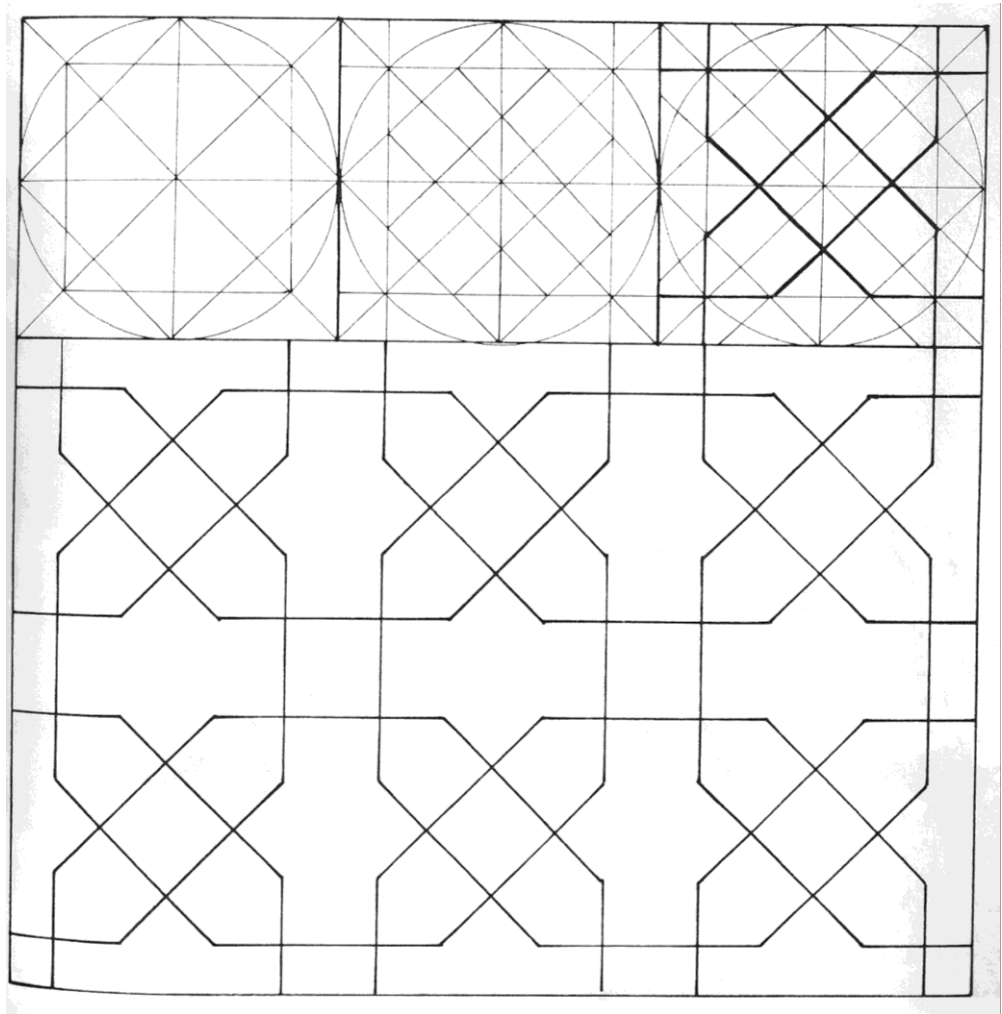
1. Using construction tools, students construct one unit of their chosen Islamic pattern from the selection (see below), following steps shown.
2. Tracing paper is used to repeat unit to create overall pattern.
3. Extension: try creating your own Islamic style pattern.



APPENDIX B: Activities (cont'd)



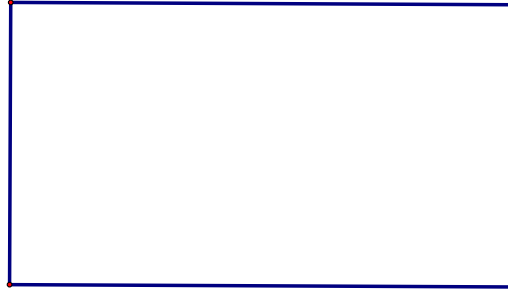
APPENDIX B: Activities (cont'd)



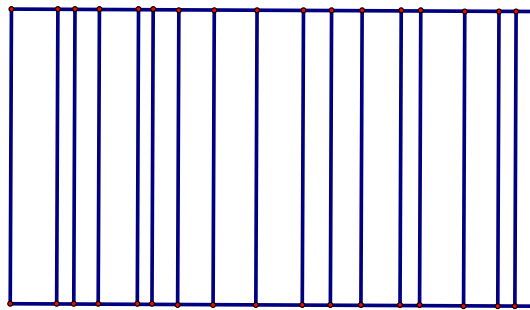
APPENDIX B: Activities (cont'd)

Op-art

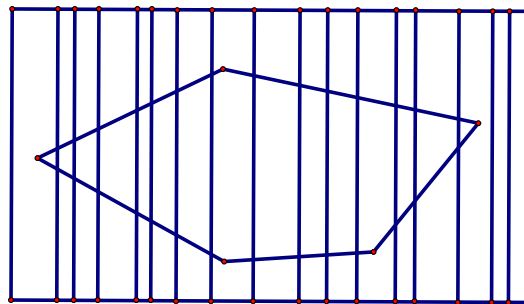
1. Construct a rectangle.



2. Construct randomly spaced parallel lines, perpendicular to the base of the rectangle.

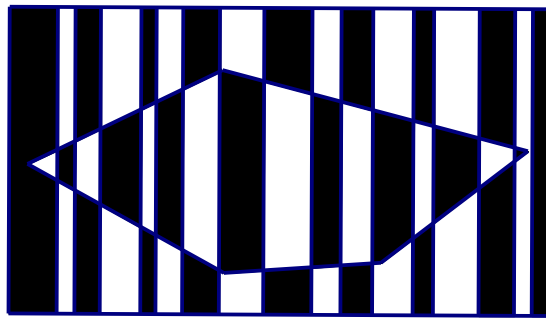


3. Draw a polygon inside the rectangular border, making sure the vertices of your polygon do not touch the vertical segments.



APPENDIX B: Activities (cont'd)

4. Colour your design using black and white or other colours. Adjacent bands should be filled with alternate colours, and, within each band, the colour inside the polygon should be the opposite of the colour outside.

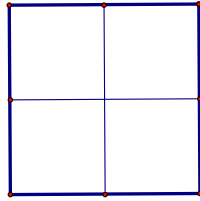


You can make your design as complicated as you like, using any polygon, curves, or even words!

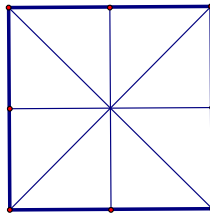
APPENDIX B: Activities (cont'd)

Quilt Patterns

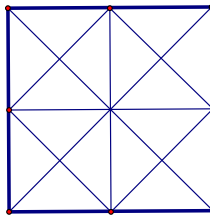
1. Cut a square from plain paper and fold it in half vertically and horizontally to make a 2×2 grid.



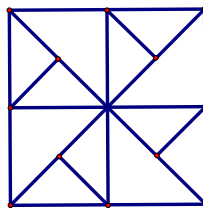
2. Now fold it diagonally both ways.



3. Then fold each corner to the centre to divide the square into 16 triangles.

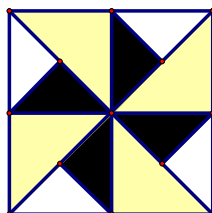


4. Draw in some of the lines made by folding. Keep the design symmetrical.
(One possible design is shown below.)

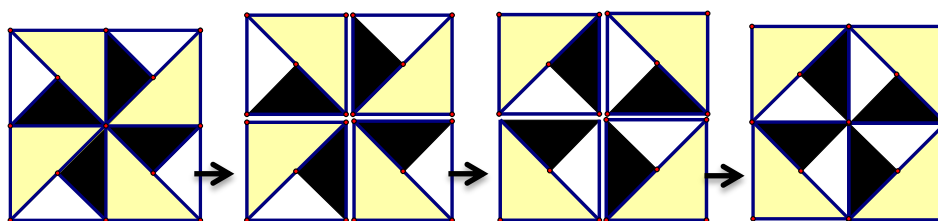


APPENDIX B: Activities (cont'd)

5. Colour in some of the shapes on the square. Copy this design into your notebook.



6. Cut the design into four smaller squares and rotate them. Put the squares together to make a new design.

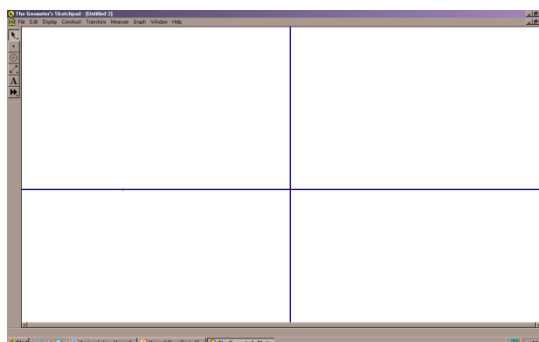


7. Copy your new design into your note book. Then divide your design into the four squares and rotate again to make a new design. How many designs can you make?
8. Choose the one you like best and stick it down.
9. Extension: repeat the process with a 4×4 grid. Four by four grids can be cut into four squares and rotated in just the same way as the 2×2 ones. The designs made by 4×4 grids are much more complex and varied than the 2×2 patterns. So go on and EXPERIMENT!

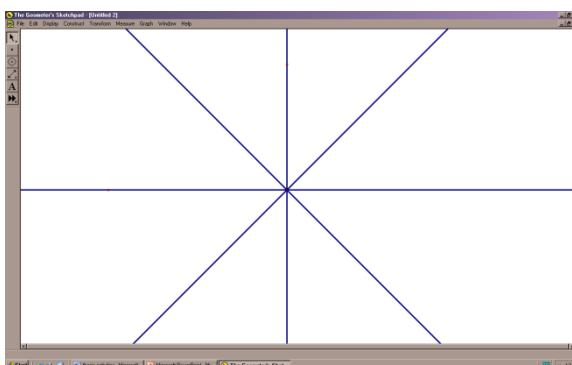
APPENDIX B: Activities (cont'd)

Animated Snowflake

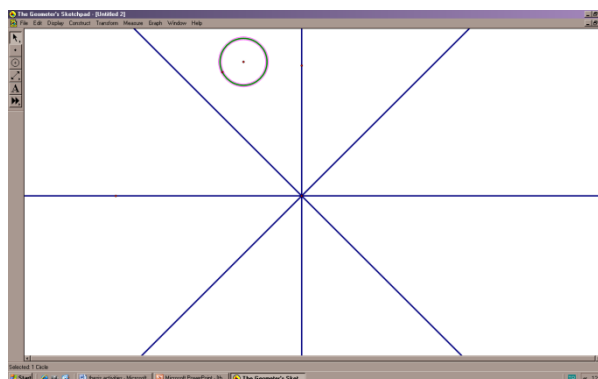
1. Using the Geometer's Sketchpad program (G.S.P.), construct a pair of perpendicular lines in the centre of the screen.



2. Construct the angle bisectors of each quadrant.

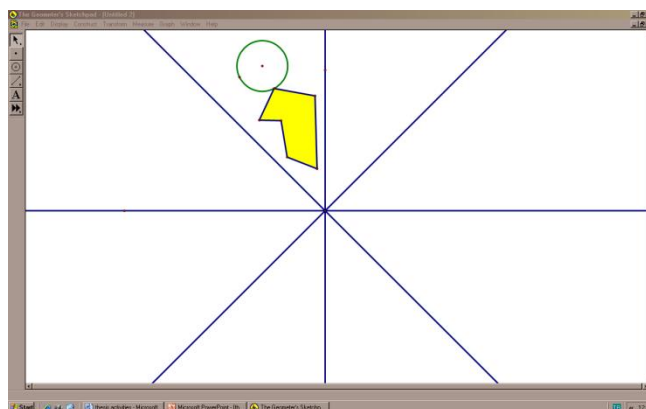


3. Construct a circle in one of the eight regions.

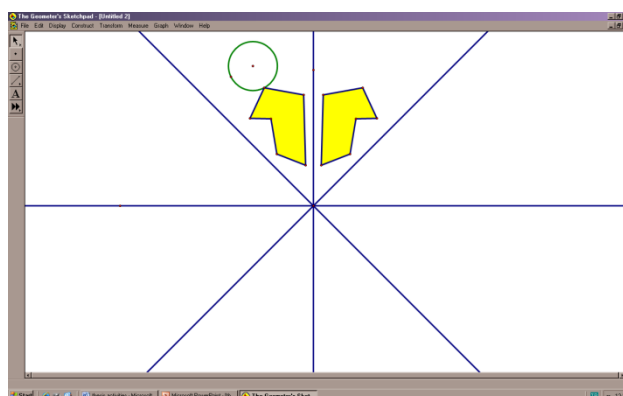


APPENDIX B: Activities (cont'd)

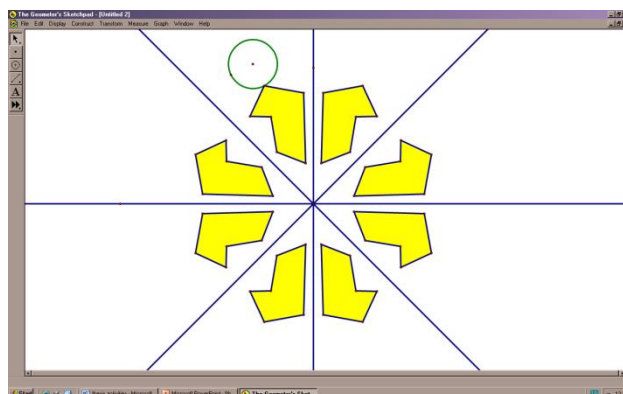
- Using the segment tool and starting from a new point on the circle, construct an irregular polygon in the same region as the circle. Colour its interior.



- Mark the vertical line as a mirror and reflect the polygon.

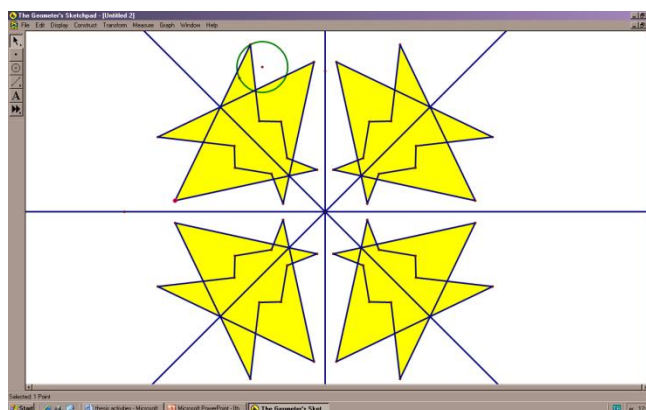


- Continue marking mirrors and reflecting until all regions have been filled.

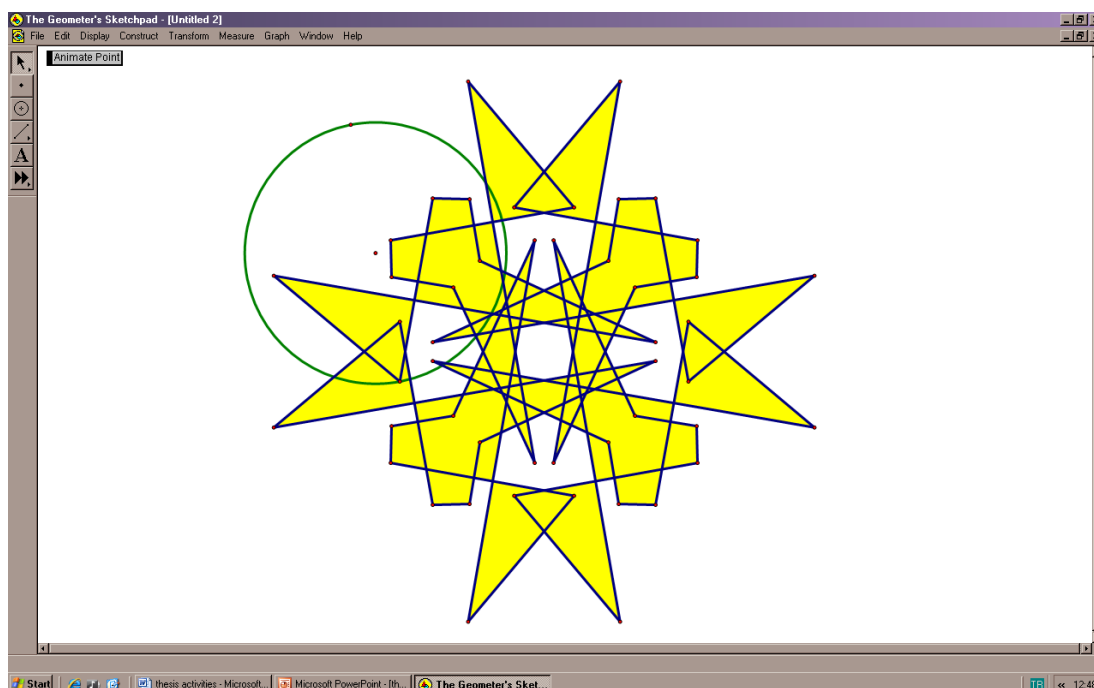


APPENDIX B: Activities (cont'd)

7. Investigate what happens when a point is dragged.



8. Select the vertex point of the polygon on the circle and animate it using the action button. Hide the perpendicular and angle bisector lines. Try changing the size of the circle and the position of its centre.



APPENDIX C: Questions for interviews and focus groups

1. What did you like about the activity? Why?
2. Did you feel confident when you were doing it? How difficult did you find it?
3. How much effort did you put into your work? Were you motivated to complete the task?
4. What mathematics is there in your finished work?
5. Do you think there is a place for art in mathematics?
6. What is mathematics?