The Application of Computer Technology in the Teaching of Junior High School Geometry

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Introduction

With the introduction and application of computer software in the secondary mathematics curriculum, a new description has emerged. As the name suggests, dynamic geometry encompasses learning activities that explore geometric principles through interactive manipulation. This is not to say that dynamic geometry is a new learning experience. Indeed, geometry has been taught with a practical orientation since Egyptian times (Mason 1995). Rather, the application of computer technology seems to have given particular relevance to the term dynamic, as it describes a new and exciting interactive way to learn geometry. While other information technologies such as graphics calculators, videos or the internet are pertinent to mathematics, the sheer diversity of suitable educational technology prevents the discussion from being wider. Accordingly, this paper investigates some of the more common software packages, their application and possible implications to the teaching and learning of junior secondary geometry. Furthermore, through this discussion the potential of dynamic geometry may also be realised.

Why Geometry?

Geometry occupies a substantial and special place in the secondary mathematics curriculum, largely because of the rich variety of concepts it comprises. Psychologically, geometry represents the abstraction of visual and spatial experiences like shape, measurement, mapping and pattern. Mathematically, geometry plays an essential role in developing skills for problem solving through, for example, drawings, transformations, vectors and coordinate systems, to name a few (Davey and Holliday 1992; Burger and Culpepper 1993). Furthermore, the development and use of such skills and concepts maintain an important place in daily life after leaving school. Statements from administrative bodies like the Australian Association of Mathematics Teacher on the use of calculators and computers in mathematics (1996) and the Curriculum Development Centre with the National Statement on Mathematics in Australian Schools (AEC 1991), have invoked a dramatic increase in the use of technology in the mathematics curriculum. Combined with the recent availability of excellent educational software, it is not surprising that the application of technology in mathematics has made its greatest mark in geometry (Burger and Culpepper 1993).

Deductive to Dynamic

Many students find the conceptual and problem-solving aspects of geometry stimulating and useful, but the formal study of geometry difficult and frustrating. Only recently has research provided insight into the conflicts that exist between the psychological and mathematical issues involved in teaching geometry. The application of such research has initiated a shift from the strictly deductive approach, taught for more than a century, to dynamic methods aligned with constructivism (Stewart 1997).

Of particular importance, is the work of van Hiele with his model of geometric reasoning (cited in Pegg and Davey 1991). Analogous to a combination of Piaget's stages of development (1960) and Bloom's levels of thinking (1974), van Hiele observed that formal reasoning in geometry did not occur naturally in children, and so required systematic nurturing. The five sequential levels of geometric thinking beginning at the lowest include recognition, analysis, informal deduction, formal deduction and rigour. Each level is characterised by particular language, symbols, and methods of inference. In the past standard geometry texts have expected students to employ formal deduction from the outset (Hoffer 1981). Fortunately, over the last decade, curriculum development and changes in geometry texts, consistent with the van Hiele model, have encouraged the inclusion of the first three levels, and a process of discovery. What holds greater promise, however, is the parallel development of geometry software that embodies the van Hiele model and makes dynamic geometry possible.

Dynamic by Name, Dynamic by Nature

According to Arnold (1996), software tools that exemplify the most positive features of computer technology as a medium for learning should:
• encourage and reward exploration and inquiry,
• place the user firmly in control of the technology,
• offer capabilities impossible without the use of technology,
• extend and support the mathematical capabilities of the user, and
• immerse the user in mathematical concepts and actions.

Although pioneering software packages such as Logo and Geometric Supposer come some way to fulfilling these desirable qualities advocated by Arnold (1996), it was not until the development of software like Geometer's Sketchpad and Cabri Geometry that spatial concepts were ultimately brought to life. Indeed the main goal of Sketchpad, according to the designers, was to bring students through the first three levels of the van Hiele Model (Klotz 1991). Kissane (1995) and McCoy (1992) encourage this new genre of software as a facilitator of exploration and high level problem solving. Although much of the past research has focused on Logo and Geometric Supposer, Kaput (1992) suggests an important need to conducting studies involving the superior applications of both Geometer's Sketchpad and Cabri Geometry.

These types of open-ended geometry exploration tools should provide a cornerstone in the software library of any mathematics faculty, and are generally referred to as dynamic geometry software. While it is important to consider software in light of Arnold's list, it is not essential for appropriate packages to fulfi! all requirements. Naturally, the choice of software will depend upon the context and situation in which it is to be used, in addition to factors associated with pedagogical design. With this in mind, there is a multitude of software packages, designed specific and non-specific to geometry that can be adapted and used to provide a dynamic geometry environment.

Application and Implication

The implications of computer technology use in geometry, and in any curriculum area for that matter, are many and varied. Even just one computer in a classroom has the potential to change the whole social process, the role of the teacher and methodology used (Heid and Baylor 1993; Roblyer 1996). The following section highlights a number of such issues pertinent to the geometry curriculum, but transferable to other disciplines.

First and foremost, the successful application of technology in the mathematics classroom ultimately depends on the teacher. The main obstacle is generally not the availability of computers, but the lack of teacher training and development (Borba, De Souza, Fey and Hudson 1997). The open-ended nature of dynamic geometry requires teachers to have a high level of subject knowledge and confidence in their own mathematical ability. It is no longer possible to stay just a few pages ahead. Just as teachers evaluate the appropriateness of texts and reference books, they will also need to evaluate the merits and possible applications of geometry software. With an intimate understanding of the subject and the software package, the main challenge faced by teachers is the ability to design lessons that optimise learning objectives in a supportive yet dynamic environment by matching the right software package to the learning activity.

Secondly, dynamic software packages like Sketchpad and Cabri are so user friendly and diverse in their application, that it is difficult to find a part of the geometry curriculum that could not be adapted. However, Matras (1991) warns that the computer should be used in the classroom for the same reasons that technology is used in the home. The humble broom still has an important place in the home, despite the invention of the vacuum cleaner. Similarly, there are objectives in geometry for which the pencil is still a necessary tool. For example, isometric drawing and cube construction (Figure 1) is a key learning objective in the year 8 Geometry syllabus. As a direct response to this syllabus, a CD-ROM by the Curriculum Corporation (1996) called Working Mathematically: Space, was specifically designed allowing, among other things, students to manipulate cubes in a 3D isometric environment. While students are able to generate cube constructions efficiently and certainly much faster, than by pencil and paper, the very skill of drawing is not being developed. As an important learning objective and necessary life skill, students need the opportunity to learn how to draw.

![Figure 1. Example of an isometric cube construction](image)

Thirdly, in the tradition of Newton's 3rd Law (for every action there is an equal and opposite reaction), the application of dynamic geometry software has influenced curriculum reform. Reflective of the constructivist and van Hiele theories, the application of appropriate supportive software has provided a means to effectively implement such change. With a resulting shift in
educational priority, the Australian Association of Mathematics Teachers (1996) recommended an increased emphasis on broad-based, exploratory approaches in high school geometry, and a decrease in emphasis of repetitive algorithms such as formal deductive geometry proof. A corresponding shift, from students as knowledge accumulators to students as information managers, further supports positive curriculum reform.

Lastly, the application of dynamic software should not only be viewed as a means of achieving geometry objectives more efficiently, but also as a means of achieving those objectives in alternative ways. Morgan (1996) suggests four checkpoints that teachers should use to determine and evaluate the curriculum changes necessary.

1. How does technology provide students with multiple exposure to variations of concepts?
2. How does technology increase student productivity?
3. How does technology actively involve students in the learning process?
4. How does technology engage students at higher levels of Bloom's Taxonomy?

These questions are designed so as to link the implementation of technology to the cognitive theories about how students learn. Again, the isometric cube drawing serves as a good example. Once students have demonstrated the skill of isometric drawing which only engages Bloom's lowest cognitive levels, then the objectives of subsequent learning activities should not focus on the further demonstration of that skill. The use of software such as Working Mathematically - Space, provides an excellent environment to satisfy Morgan's checkpoints. A typical assignment may involve the design and investigation of all the possible combinations of a four-cube house, as suggested in MCTP (Lovitt and Clark 1988). Traditionally, this popular activity had involved students' arranging blocks and then drawing the designs. By using appropriate software, such as Space, the main focus is transferred away from the construction aspects to the analysis and evaluation of the designs.

Of greater interest, however, is technology's ability to access the previously inaccessible and thus develop new objectives. The graphical genius of Escher provides inspiration. A 3D builder like Working Mathematically - Space, can be used to construct impossible 3D images (Figure 2), a trademark of Escher's work. Further stimulus is provided by Escher through the artistic world of tessellations, now an important part of the Year 8 and 9 Geometry programs. While an initial introduction to the mathematics behind tessellations can be achieved using Geometer's Sketchpad (Figure 3), design-specific programs like TesselMania simplify and automate the construction process. However, the mathematical understanding behind such designs may not be as apparent.

At the frontier of curriculum reform is the intriguing and beautiful world of fractal geometry. Bedford (1998) acknowledges that the field is so young that a common syllabus is still to be agreed. However, this very situation affords the unique opportunity for secondary school teachers and students to participate in the design of an emerging field. Such a global fascination in fractal geometry has yielded a multitude of interactive software packages of varying complexity and approach. Dynamic software packages such as Paper Folding Fractals allow students to explore the concepts of fractal generation without the difficulties associated with complex number analysis. Other packages such as Aros Fractal Magic provide basic fractal sets like the Mandelbrot Set shown in Figure 4, and encourage the concept of infinite complexity. All have the potential to spark interest, provide motivation and immerse the student in geometry-related concepts.
Concluding Remarks

By briefly describing the path along which the current geometry curriculum has come, it is hoped that this paper has provided insight into the direction that it may be heading. The Australian Education Council made the following appropriate comment:

Computers change not so much the nature of the discipline as its scale: computers are to mathematics what telescopes are to science. (Australian Education Council, 1991:6)

Clearly, dynamic geometry software has the potential to take both student and teacher alike, out of the two-dimensional world of pen and paper deduction into the three-dimensional universe of interactive investigation. By posing, investigating, and extending problem situations, an environment can be established in which students (and teachers) can recognise the power and usefulness of mathematics. Used appropriately in that environment, dynamic software becomes a valuable tool for learning.

References


Software