

# The Beam Analysis Tool (BAT)

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## INTRODUCTION

In Houghton's (1989) review of educational paradigms, he highlights the gaining importance of chaos theory. Chaos theory is often characterized by the term non-linear. Chaos theory can be found in many disciplines; in structural engineering, the behaviour of a structure under earthquake loads is often seen in terms of non-linear behaviour. Another characteristic of chaos theory is unpredictability. The implications for educational theory, as Houghton suggests, is that we have a realistic model for what happens in highly interactive systems.

If the process of teaching and learning is seen as a highly interactive environment, then the parallels to chaos theory can be easily seen. The nature of a lecture can change when a student asks a question. This results in a non-linear learning environment. Students affect how something is taught by their own unique ways of understanding. Houghton (1989) suggests that the use of computers in education is supported by chaos theory. He suggests that computers should play a significant and active role with learning. Chaos theory not only supports the concept of using computers in education, it suggests that with non-linear programming (e.g., hypertext), education can change from the traditional linear format to a non-linear methodology that is alive and vibrant.

## BACKGROUND

Many theorists have been focusing on the importance of introducing non-linear methodology into education. Often, computer software is seen as the ideal method for implementing such a methodology. Saint-Germain (1997) identified teaching styles as an important factor in the use of multimedia and non-linear capable teaching software. She notes that previous conceptions of

non-linear education were centered on developing software that complemented teaching styles rather than the other way around.

Gardner (1993), in his theory of multiple intelligences, theorized that people learn in different ways and, traditionally, education is not equally effective for all people, as it tends to favour certain types of learning. Lampropoulou (2001) recognizes the potential of computer-based or computer-assisted learning to address this concern. Well thought-out multimedia instruction could focus on more of Gardner's learning styles than traditional lectures and improve access to education. Computer use could not only help to improve student understanding, but also allow traditionally marginalized groups to access education in a manner that might be better suited to their learning style. Lampropoulou describes learning as often being of a non-linear nature and sees multimedia as one of the possible applications of computer technology, with a great potential to learning.

Boger-Mehall (1997), drawing on the work of Spiro, Feltovich, Jacobson and Coulson (1992), supports the use of a non-linear teaching methodology for teaching complex, ill-structured subject matter. The basis of this approach is rooted in the theory of cognitive flexibility. This theory is based on constructivism and the idea that students construct their own learning based on their own experiences. Spiro et al. suggest that when the subject matter is complex, traditional linear instruction may be ineffective (Boger-Mehall, 1997). The traditional linear instruction model will cause an oversimplification of key factors, resulting in a student's difficulty in transferring this knowledge into a new situation. She suggests that the goal of many professional educational programs is to help students transfer their knowledge into new and unique circumstances.

The use of computers to facilitate non-linear instruction is seen to be a natural progression. This approach is well-suited to the subject of mechanics of materials,

where the application of principles is needed for success. The various components of mechanics of materials are not organized in a linear manner. Often, components from one theory are needed to explain another theory, and vice-versa. Cognitive flexibility theory provides a potential solution to the problem. Again, the use of computers is seen as the ideal mechanism to accomplish this. This process can be explained with the following statement:

*Ill-structured aspects of knowledge pose problems for advanced knowledge acquisition that are remedied by the principles of Cognitive Flexibility Theory. This cognitive theory of learning is systematically applied to an instructional theory, Random Access Instruction, which in turn guides the design of non-linear computer learning environments we refer to as Cognitive Flexibility Hypertexts. (Spiro et al., 1992, p. 59)*

Ashmann (2000) also supports the use of non-linear computer-based methods for displaying information. He sees the main advantage as the ability of the reader to choose which links to follow in whatever order seems logical. Ashmann focuses on the American science standards, where he notes that displaying information in a list leads to the implicit assumption that the first listed item is the most important. The use of a Web-based system with appropriate graphics and hyperlinks can eliminate this assumption and allow readers to view the material in the manner that seems most appropriate for them. Ashmann continues by indicating that the use of colour on the graphics can lead to important connections.

Unfortunately, the computer-based options for supplementing the teaching and learning of mechanics topics are primarily linear in nature, and most are geared towards a very basic level. Existing computer-based resources can be broken into three distinct types: Web-based information, computer algebra systems and specific computer programs. Web-based information consists of Web sites on the teaching of mechanics (e.g., Fanous & Billingsley, 2003) and publisher Web sites to accompany textbooks (e.g., Prentice Hall, 2003). Hillsman and Tomovic (1995) support the use of computer algebra systems to teach beam deflections. They suggest that generic computer algebra systems such as Mathematica, MathCad and Maple can be used to speed up the calculation process and allow students to examine more beam configurations within the same

amount of time. Blackmon and Fenves (1997) have developed the STructural Analysis Resource (STAR) tool. This tool allows students to construct the objects needed for any given mechanics of materials problem, and then the STAR tool will create a spreadsheet or the input file for a computer algebra system. This allows students to concentrate on the concepts rather than the mathematics. Other specific computer programs for teaching and learning mechanics include Dr. Beam (Miller, 2001), MDSolids (Philpot, 2001), Statics Tutor (DeVore, 2000) and a concrete beam design program (Rostom, 2003).

Perhaps the most significant research in this area has been conducted by Shepherdson (2001). Her research has focused on the fundamental concern that students lack adequate understanding of the basic concepts. Her focus was in the area of structural mechanics. Shepherdson developed a new software program to help combat this problem, but her resulting software is still linear in nature and aimed at a very introductory level. While Shepherdson's software is intended to emulate a tutor, it provides little true interaction and behaves in a manner that leads the student through a predetermined path.

Other research efforts available within engineering education not specific to mechanics of materials provide an insight into current research into computer-based engineering education. One of the current trends is towards the development of "tutor" systems that attempt to emulate a live tutor. Zaitseva and Zakis (1997) have been focusing on creating tutoring systems. They also recognize the importance of aesthetics in the design of the software. They specify the need to develop both a model of the subject matter as well as a model of a specialist. They stress that it is important to identify what knowledge is needed for someone to be a considered a specialist in a particular subject and to include all of the relevant material in the design of the software.

Scott and Stone (1998) have been experimenting with computer-based tutorial systems that ask students to solve carefully selected problems and attempt to determine the type of error that occurred in wrong answers by codifying typical errors. Their research has been in the area of engineering dynamics. They recognize that there are many cognitive steps leading from the problem to the solution. They look to provide an explanation to students of why something is wrong, not just that it is wrong. Questions are designed to "trap" common misconceptions. The main problem with this approach

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