Digital animations as a visual learning tool for Structural Analysis

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***Abstract**: A number of digital animation clips have been developed to explore the effectiveness of their use in teaching of the subject Structural Analysis at the University of Technology, Sydney.*

The subject Structural Analysis is perceived by most students as challenging not only because of the theory and analysis concepts covered, but also because in its application it is difficult to visualise how structures behave when subjected to loads. The animation clips that were developed bring 'movement and life' to structures that are traditionally presented in textbooks as static. It is anticipated that this will assist students to visualise the behaviour of structures and to better understand difficult concepts and methods taught in the subject.

The intended uses of the animations are (1) in-class demonstration of behaviour of structures and methods of structural analysis and (2) as a self learning tool for students. This paper will present examples of the animations, how they have been used in teaching of Structural Analysis and feedback from students on their effectiveness.

Introduction

The subject Structural Analysis is a fundamental subject in Civil & Structural Engineering courses in which students learn how to idealise load bearing structures and study their behaviour. The subject objective is to learn how to compute quantities such as support reactions, deformations and internal actions, which are prerequisite for correct sizing of individual members and connections during the design phase. An equally important learning objective is the conceptual understanding of structural behaviour, whereby students apply a qualitative approach as a means of predicting and independently validating numerical solutions. This qualitative approach requires students to be able to visualise how for example a structure will deform, the directions of a support reaction or if the stress at a particular part is compressive or tensile. In today's age of digital computing where powerful structural analysis software is widely applied in engineering practice, conceptual understanding and the ability to analyse a structure qualitatively is becoming more important in order for the engineers to be able to prepare meaningful computer models and to validate and interpret results correctly.

The subject Structural Analysis is typically perceived by most students as challenging not only because of the theory and analysis concepts covered, but also because in its application it is difficult to visualise how structures behave when subjected to loads. One of the reasons is that most building structures are static in appearance and intentionally designed to prevent excessive deformation when loaded. As a result cause and effect are not obvious and lead to the false impression that nothing happens when a load acts on a structure. For these reasons, teachers in structural analysis often use a variety of approaches to demonstrate structural behaviour and to assist students to visualise abstract concepts. Examples are scaled down structural models for in-class demonstration, hands-on laboratory experiments or videos of such experiments or videos of structural failures such as the well known 1940 Tacoma Narrows bridge collapse. Another alternative, which is the subject of this paper, is the use of digital animations. A number of animation clips have been developed and we explore their effectiveness in teaching of the subject Structural Analysis at the University of Technology, Sydney.

Animation types and their application

Digital animation is a well known technique using computers, whereby the illusion of movement is created when a series of images of an object that changes in small increments between frames is displayed as a continuous sequence. Many animation packages for general purpose use are readily available and most engineering softwares include animation as a modelling aid and to illustrate numerical results. Research literature does not universally support animation as a means of increasing learning outcomes (Tversky et al, 2000; Rasch & Schnotz, 2009). However comparative experiments between animations and static graphics has resulted in the following advice for 'animators': "…This means that animations should lean toward the schematic and away from the realistic."(Tversky et al, 2000,p.258)

In line with this advice, two alternative approaches were adopted to generate the animations for the subject Structural Analysis. In the first approach when the objective was to create animations showing contour plots of internal stresses or when numerical analysis was needed for ease of plotting the correct deformed geometry of a structure, Finite Element software was used (Ansys). An example of such an animation is the L-Frame of Figure 1. In the second approach, when the objective was to prepare animations that portray a concept or analysis procedure, general purpose software was applied (Flash CS3). A typical example is the animation of the Moment Distribution iteration procedure depicted in Figure 2. Many of the animations were prepared as part of a Final Year student project at UTS (Morphett, 2007).

The animations prepared for a pilot study in Autumn semester of 2009 covered five key structural analysis topics: Statics, Qualitative Analysis, Influence Lines, Force Method and Moment Distribution. The animation clips had a duration ranging from a few seconds to two minutes. They were used for in-class demonstrations and were also made available to students to use as a learning resource through the Structural Analysis subject website.

Apart from being able to pause and replay an animation clip as required, a clear advantage is the ability to use the same clip to demonstrate different concepts and to reinforce the links between different design parameters and their effect on the behaviour of a structure and hence the analysis results. As an example consider the animations of the L-frame of Figure 1, which can be used to demonstrate the following: The relationship between deformation, point of inflection and internal actions; The difference between rigid- and non-rigid deformations, which is associated with strain, stress and hence internal forces or moments actions; The importance of recognising and applying correct support conditions and internal releases and how incompatibility at supports or internal deformation inconsistency can substantially change internal actions. Another example, which is shown in Figure 2, is the animation clip demonstrating the Moment Distribution procedure as it is applied to a continuous beam. During the animation, students can see how the initially unbalanced joint moments are gradually eliminated while at the same time the bending moment diagram is adjusted and the corresponding numerical values appear in the table below.

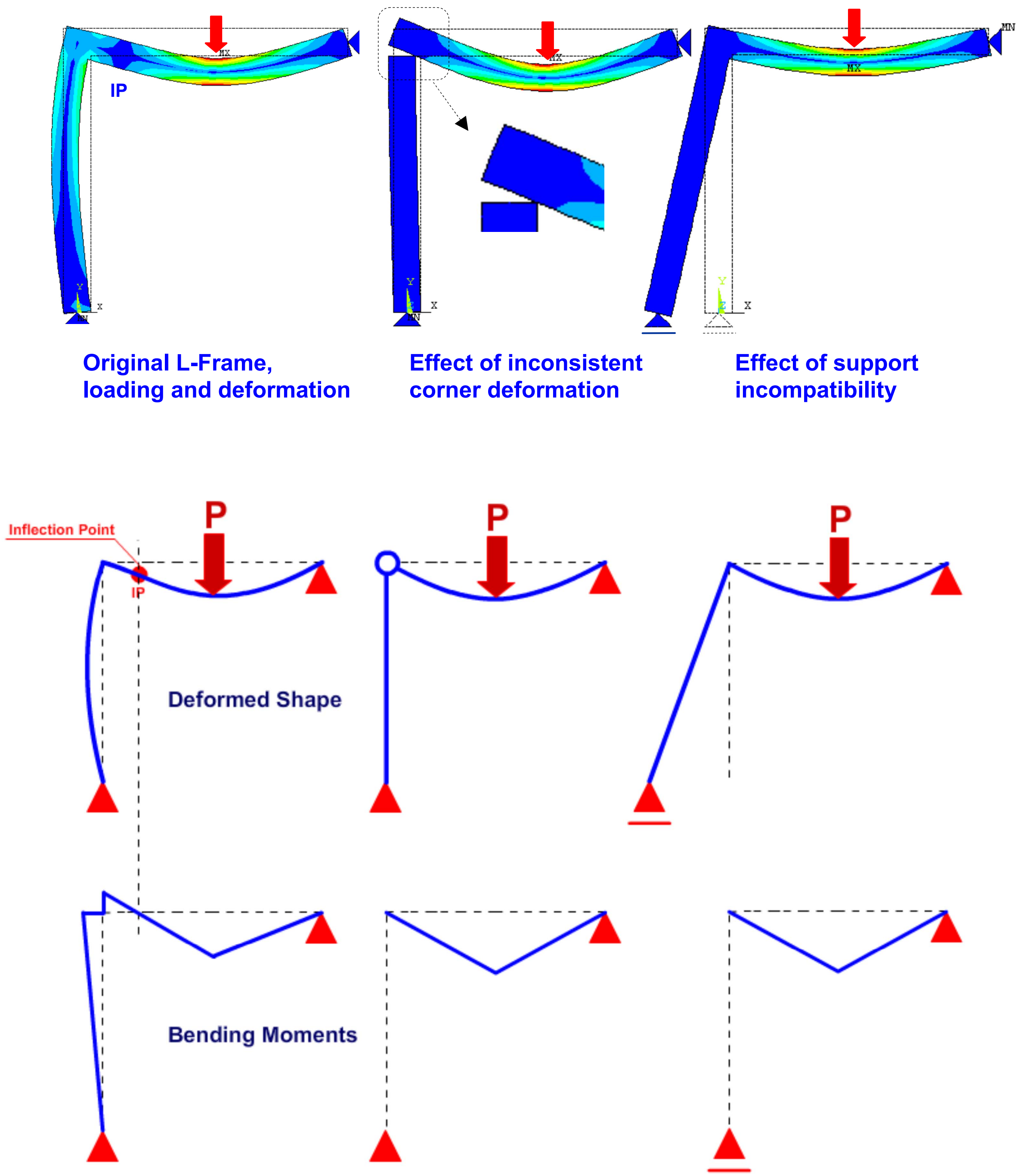

Figure 1: Screen shots of L-Frame animation showing the effects of different support conditions and internal releases on deformation, internal stress distribution and bending moment diagram.

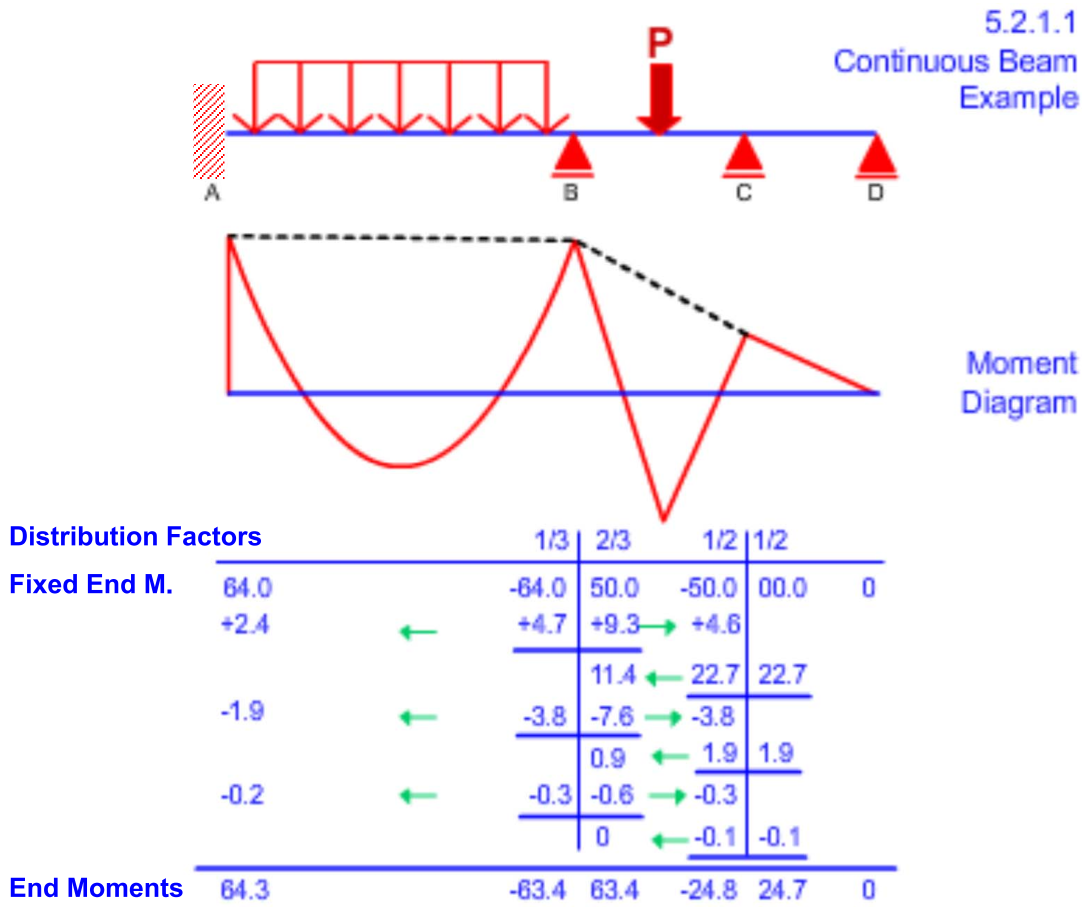

Figure 2: Screen shots of animation showing the Moment Distribution procedure applied to a continuous beam.

Student feedback – method, results and discussion

According to various dictionary definitions, animation can be described as the quality or condition of being alive, active, spirited, or vigorous or as the act, process, or result of imparting life, interest, spirit, motion, or activity. Some of these definitions were reflected in student responses to a survey conducted at UTS in Autumn 2009 in the subject 48349 Structural Analysis.

In the Autumn semester of 2009, 130 students were enrolled in Structural Analysis, which was split into two classes taught by two different lecturers. The animations were used in both classes. In the last lecture of the semester, students were asked to complete a survey on the use of the animations. This survey was a mixture of types of questions including Likert scale and open-ended questions. Eighty four students responded to the survey giving a 65% response rate. The surveys from both classes were combined to give an overall result for the subject.

Our research questions were: Did students use the animations? Do students think the animations helped their understanding of these topics? What could we do to improve them – the animations, not the students?

The responses to the survey were collated to provide the frequency histograms shown in Figures 3 – 6.

Figure 3 shows that the most common number of times the animations were accessed outside of class time was between 2 and 5 times. The number of responses for this frequency of access (54%) was significantly higher than the next most frequent response of 21% for those who accessed the animations only once outside of class time.

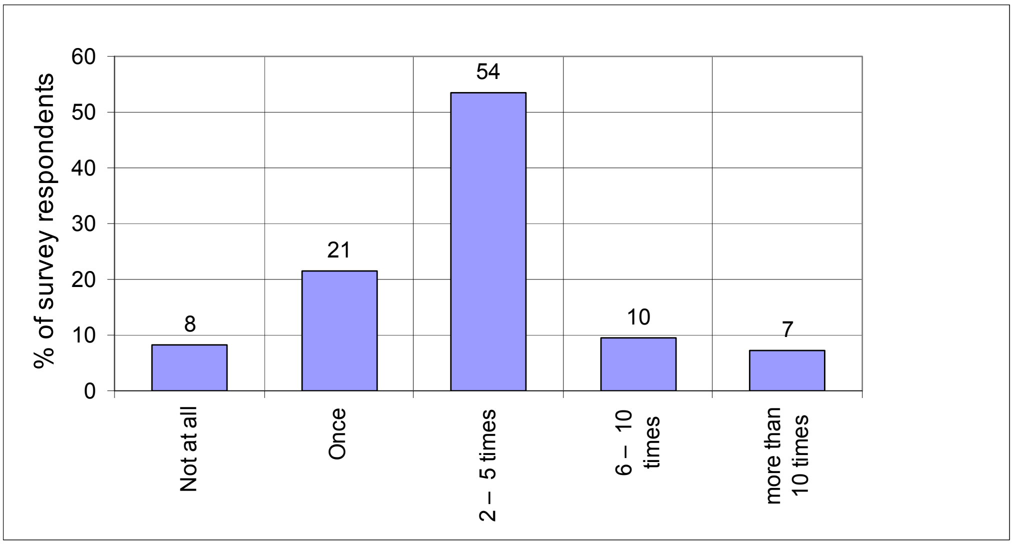

Figure 3: % of survey responses to the question: *I accessed one of the structural animations on UTSOnline during this semester to try to understand some aspect of structural behaviour*

Apart from finding out whether students accessed the animations, we are also interested in whether the animations had any effect on students' perceptions of their learning. Student responses (see Figure 4) show that 68% of students either agreed or strongly agreed that the animations that they did access increased their understanding, with a further 25% slightly agreeing. So although students may not have accessed the animations as frequently as we would like, when they did access them the animations made a definite contribution to their understanding of that topic

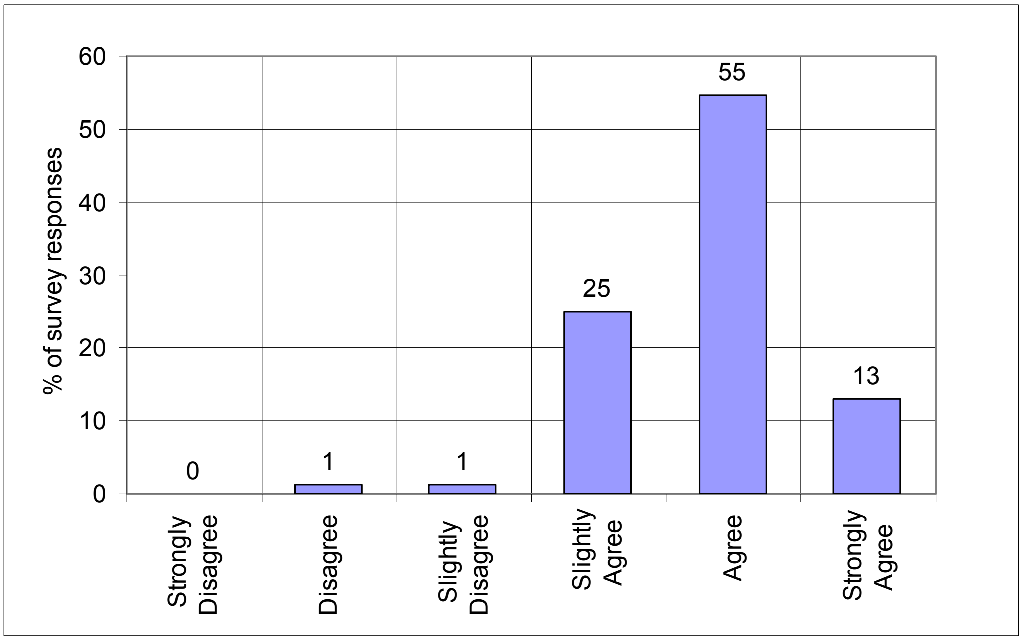

Figure 4: % of survey responses to the question: The animations that I accessed increased my understanding of those structural concepts being animated

Figure 5 shows that more students strongly agreed that the animations increase their understanding when they were used in class with the benefit of the lecturer's added explanations of the concepts being studied. Figure 6 shows how much the students think their understanding had increased as a result of using the animations. These results show that the majority of students (68%) think that their understanding has improved by at least 50%. These results show a significant increase in students' perception of their understanding of the structural concepts and methods demonstrated in the animations.

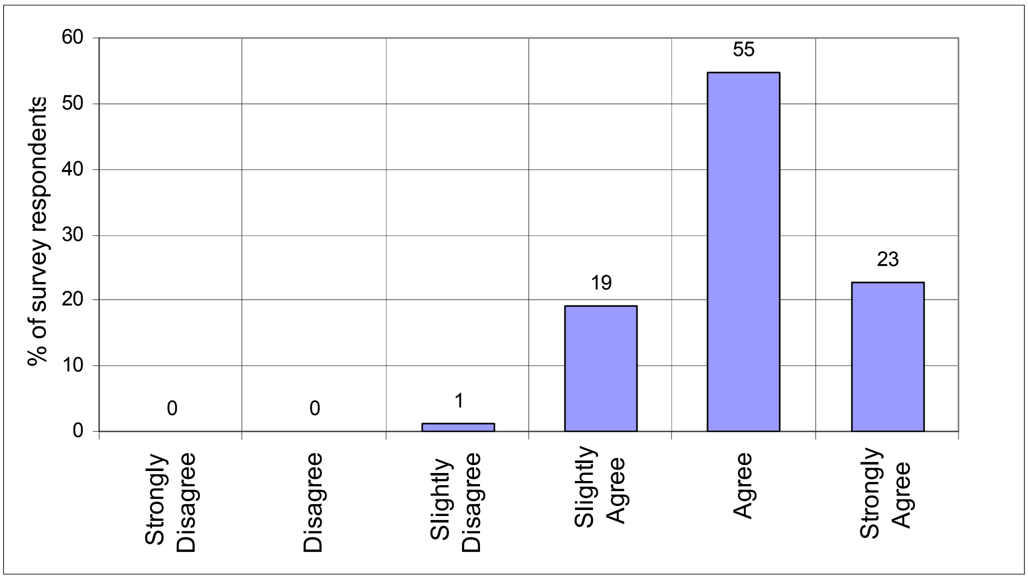

Figure 5: % of survey responses to the question: The animations that were used in class increased my understanding of the structural concept being demonstrated.

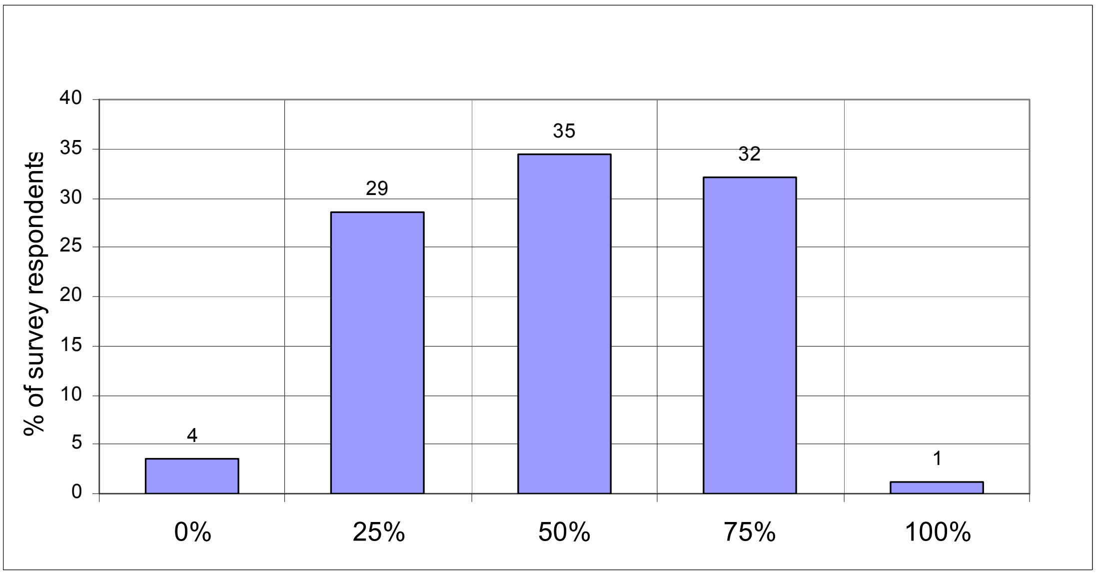

Figure 6: % of survey responses to the question: I think that the animations that were used in class, and any that were accessed on UTSOnline, increased my understanding by: (Mark the % on the indicator bar below)

Two open-ended questions were also included on the survey instrument. These were:

- The three best aspects of the animations are: and
- The animations could be improved by:

Not all students surveyed provided a response to these questions; 86% of respondents provided at least one 'best aspect', and 65% of respondents provided some indication of how the animations could be improved. These responses were examined for recurring themes as described by Tucket (2005) and Braun & Clarke (2006).

The results of the thematic analysis of responses to the open-ended questions are presented in Tables 1 and 2. The themes (both positive and negative) are listed in order of prevalence as indicated by the % of respondents who mentioned that theme. A process of inductive analysis was used where the themes were discerned from an examination of the responses and were not pre-determined by the authors. This fits with why we posed open-ended questions in the first place – to try to elicit from the students issues relating to using the animations that we hadn't thought of ourselves. The typical student comments are a data extract of responses relating to each theme listed.

Table 1: Responses to the question: The three best aspects of the animations are:

comment relates to	% of respondents making comment	typical student comment
visualisation helps to understand the concept/s	47	"Demonstrates what cannot be seen... Helps create understanding rather than only following steps."
animations were clear/simple/easy to understand	31	"Clear information/instruction about each step of the calculations/deformation. Simple." "Easy to use and understand."
it was useful to see the solution steps/pause the animation to see the steps	22	"….Step by step method made the process clearer…."
benefits of visual showing change over time ie animation	18	"The animations show what is happening constantly while applying the loads which gives a better understanding of analysing structures." " I struggle with qualitative analysis and seeing the beam move has helped significantly."
availablility outside class being useful	7	"Available anytime and can be printed."

Table 1 shows that the most often referred to themes in responses to the question regarding the three best aspects of the animations are that the visualisation aspect of the animations help the students to understand structural concepts, that the animations are clear and easy to understand, that being able to see each step in the solution procedure was useful, and that the animation of the visual had benefits to learning over static graphics.

Table 2 shows what aspects of the animations students think could be improved. It is apparent that the colours used in the animations could have been chosen with more of an eye for the visual contrast needed between various elements to make them easier to see, especially from the back of the classroom. Students have also requested more animations and suggested that adding audio would help them understand the animations outside class. Some of these issues have already been addressed eg changing the colours. Others have been acknowledged and will be addressed as resources permit.

Comments in the open-ended questions reminded the authors that despite innovative instructional methods to help students engage in deep learning there are some students who are only focussed on assessment. One of the suggested improvements to the animations was that they could be *"...done for actual questions put in the class tests."*

Table 2: Responses to the question: The animations could be improved by:

comment relates to	% of respondents making comment	typical student comment
colour needs to be changed	42	"…Dark blue on black is hard to see. Make the animations contrast with the background more."
more detailed/longer explanations	27	"Maybe have the calculations beside the animation while it is played slowly for some of the animations. This would establish the relationship of the method being used to calculate and how the structure is deforming."
need more animations	15	"...Make MORE because it really helps with structural behaviour understanding (It's worth your time!)"
needs audio/narration	9	"I think they would be better if sound was added to them because they are a lot easier to understand when ... went through them in class than at home."
interactivity should be added	7	"Allowing us to be able to play around with applying loads to different shaped structures to allow us to gain an understanding qualitatively of what the structure will do/react to the design and loads."

Conclusions

Based on experience gained from a pilot deployment in Structural Analysis at UTS in Autumn 2009, it was found that use of digital animation clips of structural response to loads has made it easier to convey to students difficult concepts and in less class time, while simultaneously achieving deeper learning and higher satisfaction by students. Although students may not have accessed the animations as frequently as we would like, when they did access them the animations made a definite contribution to their understanding of that topic. These results lead us to recommend for the continued development and use of these animations.

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