



The Use of Scaffolding Approach to Enhance Students' Engagement in Learning Structural Analysis

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Abstract

This paper presents a reflection on the use of Scaffolding Approach to engage Civil Engineering students in learning Structural Analysis subjects. In this approach, after listening to the lecture on background theory, students are provided with a series of practice problems, each one comes with the steps, formulas, hints, and tables needed to solve the problem. Gradually, with the growing confident to apply the method as a tool to analyze structures, the amount of help provided is reduced, until finally no help is provided at all.

Using this approach, only the main background of theory is needed to be lectured. The application of the method to analyze various problems is learned by students themselves by doing the series of problems engineered with gradually-reduced supports. Students' engagement is greatly enhanced, as they are so much involved in the learning process.

Keywords: Scaffolding Approach, Civil Engineering students, Learning, Students

Introduction

Kassimali defined Structural Analysis as *"the prediction of the performance of a given structure under prescribed loads and/or other external effects, such as support movements and temperature changes"*. A structure itself refers to a system of connected parts used to support loads, for example in Civil Engineering area this may include buildings, bridges and towers (Kassimali, 2005).

Structural Analysis is one of the major subjects in Civil Engineering curriculum. At Curtin University of Technology, Sarawak, Malaysia; my previous workplace; this subject is taught in three different units, i.e. Structural Analysis 267, Structural Analysis 268, and Structural Analysis 365. Each of these units weighs 25 credit points, with the first two units are offered to second year students, while the last is for third year ones. Students are expected not only to gain the numerical skill in analyzing structures, but also to develop their understanding on its behavior. Traditionally, this subject is viewed as difficult subject by most of Civil Engineering students.

To make the subject more interesting and the learning process more engaging, several approaches have been attempted. One of them is the use of Scaffolding Approach. This approach has been chosen for topics which fall into the category of Stiffness or Displacement Method, i.e. Slope Deflection method and Moment Distribution method. These methods involve several 'rigid' steps resulted in unique solution.

To date, quite a number of reports are available on the use of scaffolding practice in many different areas of learning, for example in mathematics learning (Anghileri, 2006), in various subjects in primary schools (Lipscomb, 2004) and in teaching software design (Linder et al n.d.). However, no report is available on the use of this approach in teaching Structural Analysis for Civil Engineering students. This paper shares a reflection on the use of Scaffolding Approach on the above mentioned units, as part of the author's reflective practice.

Background

Scaffolding approach is about providing temporary supports. It is a normal practice in building construction to provide scaffolds especially to concrete structures in the early ages, as it is still developing its strength. As the structure is getting stronger, the amount of temporary supports provided is gradually removed, until finally no support at all is needed when the structure is strong enough to carry the designed loads.

It was Wood, Bruner and Ross in 1976 who introduced the term "Scaffolding" in the *Journal of Child Psychology and Psychiatry* as mentioned by Lipscomb et al (2004). They used the notion of 'scaffolding' to describe the way adult support is adjusted as the child learns and is ultimately removed when the learner does not need support anymore and becomes independent. The theory actually originated much earlier from the work done by Lev Vygotsky's

socio-cultural theory and his concept of the *zone of proximal development* (ZPD) early in the 20th century (Stuyf, 2002). He stated that there are two learners' developmental levels, i.e. the 'actual developmental level' and the 'potential development level'. The *zone of proximal development* (ZPD) is defined as '*the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under or in collaboration with more capable peers*' (Lipscomb, 2004).

In the view of ZPD, the role of teachers is to provide assistance or support to students with tasks that are just beyond students' current capability. When students' gradually develop their mastery, teachers start the process of '*fading*', or gradual removal of the temporary support. Benson, as stated by Lipscomb et al (2004), defined scaffolding in another way as '*a bridge used to build upon what students already know to arrive at something they do not know*'.

Lange in 2002, as stated by Lipscomb et al (2004), mentioned the two major steps involved in instructional scaffolding, i.e. (1) '*development of instructional plans to lead the students from what they know to a deep understanding of new material*' and (2) '*execution of the plans, wherein the instructor provides support to the students at every step of the learning process*'.

Lipscomb et al (2004) also listed the challenges and benefits of scaffolding approach. Among the challenges are: very time consuming, potential of misjudging of ZPD, inadequately modeling the desired activities or strategies, takes time to see the full benefit, and lack of specific examples and tips in the text books. However, the approach is also beneficial in: possible early identifier of giftedness, engages learners, provides individualized instructions, motivates learners to learn and minimizes the level of frustration to learn. These challenges and benefits are generally agreed by Lawson (2002) and van der Stuyf (2002).

Topics Description

Regarding the topics I chose to apply the scaffolding approach, both Slope Deflection method and Moment Distribution method are belong into the category of Stiffness or Displacement method. In this Stiffness or Displacement method, firstly it requires the satisfaction of equilibrium equation for the structure. The unknown displacements are written in term of the loads by using the load-displacement relations, and then solved for displacements. Once the displacements are known, the other response characteristics can then be determined by using the compatibility equations and member force-deformation relations (Hibbeler, 2009; Kassimali, 2005). Using Stiffness method in analyzing structures provides a unique solution. It does not require intervention from the user, such as the choice of the primary structure in the Force or Flexibility method.

Slope Deflections method is characterized by solving simultaneous equations, while the Moment Distribution method is characterized by the application of a series of '*converging corrections that allow direct calculation of the end moments*' (Hibbeler, 2009). At Curtin, these two methods are taught in two units, i.e. Structural Analysis 267 for analysing beams, and Structural Analysis 268 for analysing frames, with or without sidesways.

As scaffolding approach is useful to teach the basic skills to develop students' competency in applying a new tool (Scaffolding as a Teaching Method n.d.), I decided to adopt this practice in teaching the first unit of Structural Analysis subject, i.e. in Structural Analysis 267 for second year students. In this unit, students are introduced for the first time on the Slope Deflection method and Moment Distribution method to analyze beams under various loading and/or other external conditions.

Design of Scaffolding

In Structural Analysis 267, methods of Slope Deflection and Moment Distribution generally are delivered in the last five weeks in the semester, following a series of lessons on the analysis of determinate structures, determination of beams' deflection and rotation, and introduction of the analysis of the indeterminate structures. Prior to the delivery of the two new methods of analysis, students already gained basic skills to determine or knowledge of equilibrium, bending moment and shear force diagram, free-body diagram, fixed-end moments, compatibility, and load-displacement relations. This is the '*actual developmental level*' at the beginning of the delivery of the new topics. It is imperative to determine the right ZPD to make the use of Scaffolding Approach a success.

The two steps described by Lange in 2002 as mentioned by Lipscomb et al (2004) were followed by the author in the application of the Scaffolding Approach in teaching Structural Analysis, i.e.:

'Development of instructional plans to lead the students from what they know to a deep understanding of new material'.

This step involves the introductory part to raise students' interest on the topics, as well as to help them to connect with the prior knowledge. It is then followed by the delivery of the history and the theoretical background of the method. The delivery is normally performed in traditional lecture format within a set time frame which is normally kept minimal. After providing one or two examples on the use of the method to analyze structures, it will be followed by distributing worksheet equipped with procedures or steps, formulas, hints, tables and arrows (for Moment Distribution method),

which serve as scaffolds. The scaffolds are carefully selected and prepared to make sure the activities are within the students' ZPD.

A series of worksheets are prepared in advanced with gradual removal of supports provided. Some examples of the worksheets are shown in the Appendix section of this paper. Students will then work either in group or alone to carry out the tasks in the worksheet. At this stage, lecturer turns role to become coach, providing additional help or clarification to those in need. Students are allowed to make mistakes and to progress in their own pace. If common mistake is found, further clarification for the whole groups will be given. Student who finishes earlier will be given the next worksheet, which might be similar to the previous one to reinforce the skill or from different case. Sessions are intermittent with discussion to reflect the case they are doing or on the usefulness, benefit and limitation, and the connection of the method with students' prior knowledge.

'Execution of the plans, wherein the instructor provides support to the students at every step of the learning process.'

As students are busy with their worksheets, I take time to move around to see how they progress. In most cases, I let them make mistakes. I believe students learn from their mistakes. However, before going too far to the wrong direction, additional help or hints or clarification will be given to individuals or groups concerned, or if the common mistake is found, then the clarification will be given to the whole groups. The development of students' confidence in using and understanding the new tool to analyze structure and its behavior is the main learning outcome. Thus, it is imperative to keep the level of students' frustration minimal in every step of the process by providing just enough support. Lecturer plays role as coach for students in carrying out the task given.

Smart students normally finish all the worksheets earlier. For them, I normally prepared some more challenging problems or cases to analyze with no support provided.

Reflection

The most convincing evidence of success on the use of Scaffolding Approach in learning Structural Analysis is students' engagement. All students actively participate in their learning, not only passively listen or even engage in different activities. As lecturer role is turned to be more like coach, and personal attention is given to every group or individual, the learning environment naturally becomes more relax and the lecturer-students relationship becomes more informal, and thus invites more questions and discussions to happen. In most cases, I was able to identify my students' capability early, and extra attention was able to be given to weak students. A sense of accomplishment is normally shown by student who completes the task. She or he will then ask for the next worksheet happily. It is a sign of students' motivation to learn.

Students are led to reflect on the method, its strengths and weaknesses, and its connection with their prior knowledge. Using this approach, students are encouraged to discover the knowledge and to gain the skills by themselves. Often, students expressed their "ah ha!" or "eureka!", after acquiring some knowledge by themselves through guided activities.

However, despite the benefits mentioned above, a lot of preparation is needed to apply this approach. Most of all is the preparation of series of worksheets with carefully prepared scaffolds, which is faded or removed gradually along with students' growing competence. Since there was no examples available, the worksheets series were developed based on the 'trial and error' basis, by assuming students' ZPD. With the constraint in time and the area needed to cover, very careful attention is needed when designing the series of tasks, as this approach tends to consume more time than the traditional way. On the other hand, lecturer's role has to be minimized to the level of coach, not as dominant as in the traditional lecture. This might not be easy for the beginning as lecturer is used to teach everything.

On the series of worksheets or tasks that have been used, I found that several modifications are needed. Some supports provided are not enough to bridge the gap between students' current skill and knowledge with the skill and knowledge that they still do not know, for example in the step of determining fixed end moments. As the beams with fixed ends are already in the category of indeterminate structures, most of them are not familiar yet. The use of plastic ruler to visualize fixed-end beams qualitative deflected shape is found useful.

Overall, students have reported themselves feeling more confident and quicker to grasp the concept of Slope Deflection method and Moment Distribution method in analyzing structures, moreover their final results are comparable to those who study at the mother campus, which were taught using different approach. The following quotations are taken from the end-semester on-line eVALUate Teacher Evaluation and eVALUate Full Unit Report for Structural Analysis 267 unit. eVALUate is an online tool available at Curtin for students to provide feedback to teachers and to the units itself.

"The best teaching method I have ever seen"

"A very good lecturer. Knows this unit inside out. Approachable and gives student attention individually"

"Very helpful, built up our confidence when trying to solve problems.....and give us a good understanding on the topic"

“It was effective as it helped in grasping the concept over a short period of time”

These responses point toward an encouraging level of students’ enthusiasm and engagement in their learning.

Concluding Remarks

I have found that the Scaffolding Approach is appropriate practice to engage students in their learning, especially in learning Slope Deflection and Moment Distribution methods in Structural Analysis subject. Every student participate actively, with the stronger students are given opportunity to progress faster. Weak students are given better attention together with opportunity to progress in slower pace.

I found also that this approach is well suited to deliver the introductory part of the Slope Deflection and Moment Distribution methods, as in the case of Structural Analysis 267. For the more advanced topics, the suitability of the approach is needed more trials.

Despite some weaknesses, I found this approach is worth to apply as one of the approaches to teach Structural Analysis to Civil Engineering students. Students are helped to learn by themselves or in a group through properly designed guided tasks, which are removed gradually along with students’ growing competence.

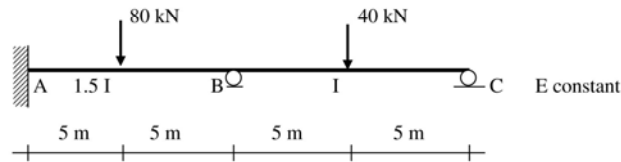
Students’ responses through eVALUate show their very high level of satisfaction upon this unit and upon the teaching style adopted, and moreover their results are comparable to those achieved by their counterparts in mother campus, which are taught using different approach.

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**APPENDIX: Sample of worksheets for Moment Distribution
Worksheet #1**

Analyze the continuous beam shown below using the Moment Distribution method, and determine the support reactions, draw the shear force diagram, bending moment diagram, and qualitative deflected shape of the beam!



Fixed-End Moments (Please refer to the table for Fixed End Moments)

FEM_{AB}=

FEM_{BA}=

FEM_{BC}=

FEM_{CB}=

Member stiffness & Distribution Factor (DF)

$$K_{BA} = \frac{EI_{BA}}{L_{BA}} =$$

$$DF_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}} =$$

$$K_{BC} = \frac{EI_{BC}}{L_{BC}} =$$

$$DF_{BC} = \frac{K_{BC}}{K_{BA} + K_{BC}} =$$

Note: DF for fixed end A =0; DF for hinge end C=1

Carry Over Factor (COF)

COF_{AB}=

COF_{BA}=

COF_{BC}=

COF_{CB}=

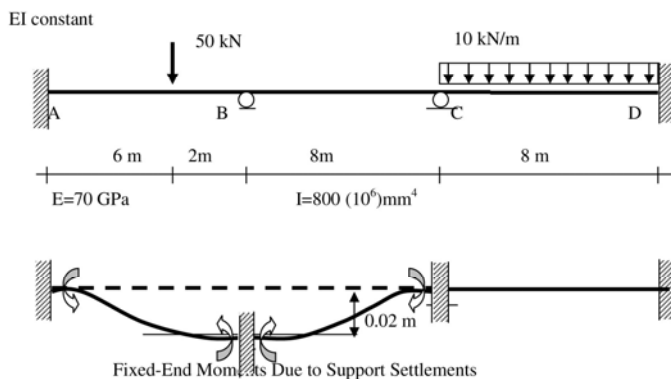
Moment Distribution Table

Joint	A	B		C
Member	AB	BA	BC	CB
COF				
DF				
FEM				
Balance				
Carry Over		↙		↘↙
Balance				
CO		↙		↘↙
Balance				
CO		↙		↘↙
Balance				
CO		↙		↘↙
Balance				
CO		↙		↘↙
Balance				
Final moments				

Check the equilibrium of the final moments, and then draw the free body diagram, determine the support reactions, draw shear force diagram, bending moment diagram & qualitative deflected shape.

Worksheet #4: Moment Distribution (Support settlement case)

Use the moment distribution method to analyze the continuous beam shown below, to determine the support reactions and to draw the shear force diagram, bending moment diagram, and qualitative deflected shape. Due load applied, support B settles downward of 20 mm.



Fixed-End Moments

- FEM_{AB}=
- FEM_{BA}=
- FEM_{BC}=
- FEM_{CB}=
- FEM_{CD}=
- FEM_{DC}=

Member stiffness & Distribution Factor (DF)

Moment Distribution Table

Joint	A	B		C		D
Member	AB	BA	BC	CB	CD	DC
COF						
DF						
FEM						
Final moments						

Check the equilibrium of the final moments, and then draw the free body diagram, determine support reactions, draw shear force diagram, bending moment diagram & qualitative deflected shape.