Initial results from the reconfiguration of an undergraduate engineering vibrations course

Les Grundman, lagrundman@indianatech.edu
Associate Professor of Mechanical Engineering at Indiana Tech

Abstract

An undergraduate mechanical engineering vibrations class is typically a requirement or an elective in mechanical engineering undergraduate programs across the United States. This subject is very difficult, requiring students to apply differential equations, sometimes studied years before, to complex mechanical systems. Many conceptual hurdles stand in the way of correctly simplifying and modeling real world systems and solving the associated differential equations; for these reasons, a vibration class requires extensive efforts by the students to pass. Unfortunately, anecdotal evidence from several recent graduates suggests that students often absorb and retain little vibration's content knowledge years after taking the class.

In an effort to improve an undergraduate vibrations class and make it more memorable and useful, the mechanical engineering undergraduate vibrations class at a small private Midwest college was reconfigured according to Wiggins and McTighe's reverse design approach, Pellegrino's ideas on assessment and David Perkin's seven principles of pedagogical design. This paper describes this reconfiguration process according to these principles and reports on the initial results of this reconfiguration as measured by a survey of students from before and after the reconfiguration.

Introduction

David Perkins(2) argued that modern university classes are often typified by the problems of elementitus and aboutitus. Perkins defined these pedagogical diseases as cramming excessive content or elements into a course (elementitus), while only learning about these elements and never actually doing anything with them (aboutitus). Undergraduate engineering vibration courses are particularly susceptible to elementitus and aboutitus due to the large amount of material to be covered and the typical lack of an associated hands-on lab. The material is also very difficult for students to learn, as the class requires abstract modeling skills and a prerequisite course, differential equations, is usually completed years before the vibrations class is started. The nature of an undergraduate vibrations class combined with comments from fellow graduate students from various universities, such as "I got an A, but I don't remember what we did or why we did it", led to a desire to redesign an undergraduate vibrations class to improve course memorability and applicability.

This paper describes the revaluation of the content of an undergraduate engineering vibrations class at a small, private engineering college and the reconfiguration of the class according to Wiggins and McTighe's reverse design approach,[3] Pellegrino's ideas on assessment[4] and Perkin's seven principles of pedagogical design.[2] This reconfiguration led not only to the difficult decision to discontinue previously covered material, but more importantly, to emphasize critically important material that had been passed over previously. The Vibration's class content was also reconfigured to include a group project to eliminate the tendency to only learn about something without ever having a chance to apply it.

The effect of these changes was evaluated by surveying students who had taken this class during the spring semester for the last five years; this timeframe included three years of students who were not exposed to these changes and then most recently, two years of students who had been exposed to this change. The effect of vibrations class reconfiguration was evaluated by coding the survey results by the category of the answer and then quantitatively comparing the results from the two groups.

Vibrations Content Reanalysis

Wiggins and McTighe[5] argued that the best curricular designs are 'backward', focusing first on the desired outcomes. Although the idea of starting with the end in mind is not new, Wiggins and McTighe called this approach 'backwards' as "many teachers begin with textbooks, favored lessons, and time-honored activities rather than deriving those tools from targeted goals or standards."[5] The three main steps in Wiggins and McTighe's backward design process are:

1. Determining the desired student results or outcomes
2. Determining what evidence will be accepted for achievement of results
3. Designing the learning experience or instruction

The first step in reconfiguring the vibrations class consisted of reprioritizing course content according to Wiggins and McTighe's categories of enduring understanding, important to know and do, and nice to be familiar with. To aid this process, the concept map in Figure 1 was created to show the traditional approach to the Vibrations class content. This hierarchal, linear approach matched Wiggins and McTighe's undesired approach of covering as much content as possible without prioritizing the importance of the material.[5] Although multiple industry examples were discussed in class to provide reference points for the material, this approach still tried to "cover it all" without determining the most important points to understand.

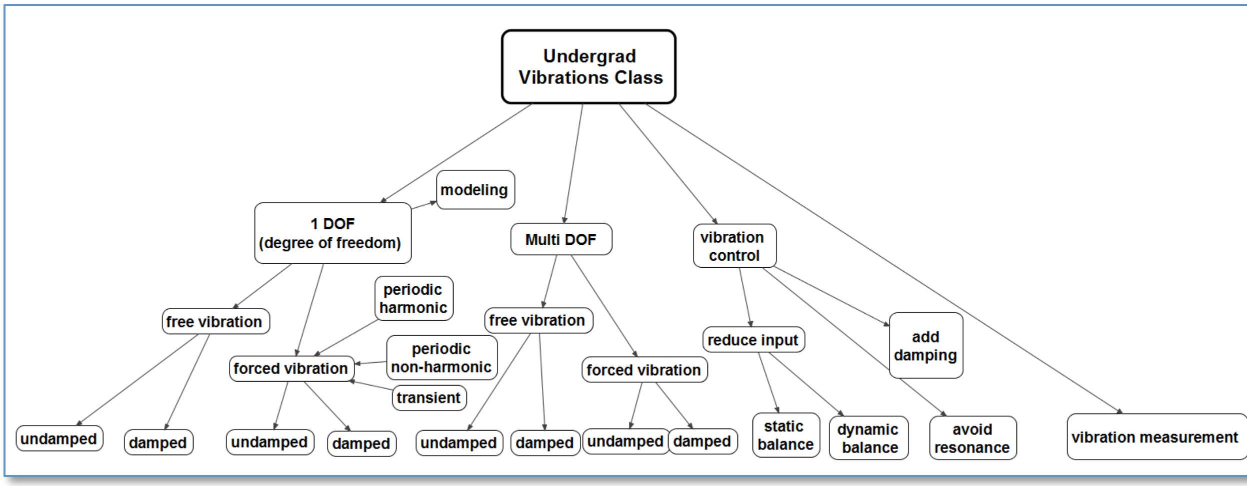

Figure 1: Initial traditional approach to Vibrations class content

Based on Wiggins and McTighe's categories of enduring understanding, important to know and do, and good to be familiar with, the content for the vibrations class was re-examined and the concept map shown in Figure 2 was created. This concept map exhibited a dramatically different topology and topic importance as compared to Figure 1. One major observation was that 'modeling', the step of creating simplified abstract models from complex physical structures, was only included by implication in Figure 1, but become a critical component in Figure 2. Upon reflection, the creation of abstract representations of complex physical structures is a key foundational step that deserved extra attention, but was previously passed over quickly.

Figure 2 also reorganized the original concept map topology to represent the iterative problem solving nature of industrial vibrations problems as informed by the author's experience. Model creation is a required input to system equation solution as are the forcing functions and initial conditions. The iterative design loops consist of changing either operating modes or system parameters to achieve the goal of vibration control using one or more control strategies.

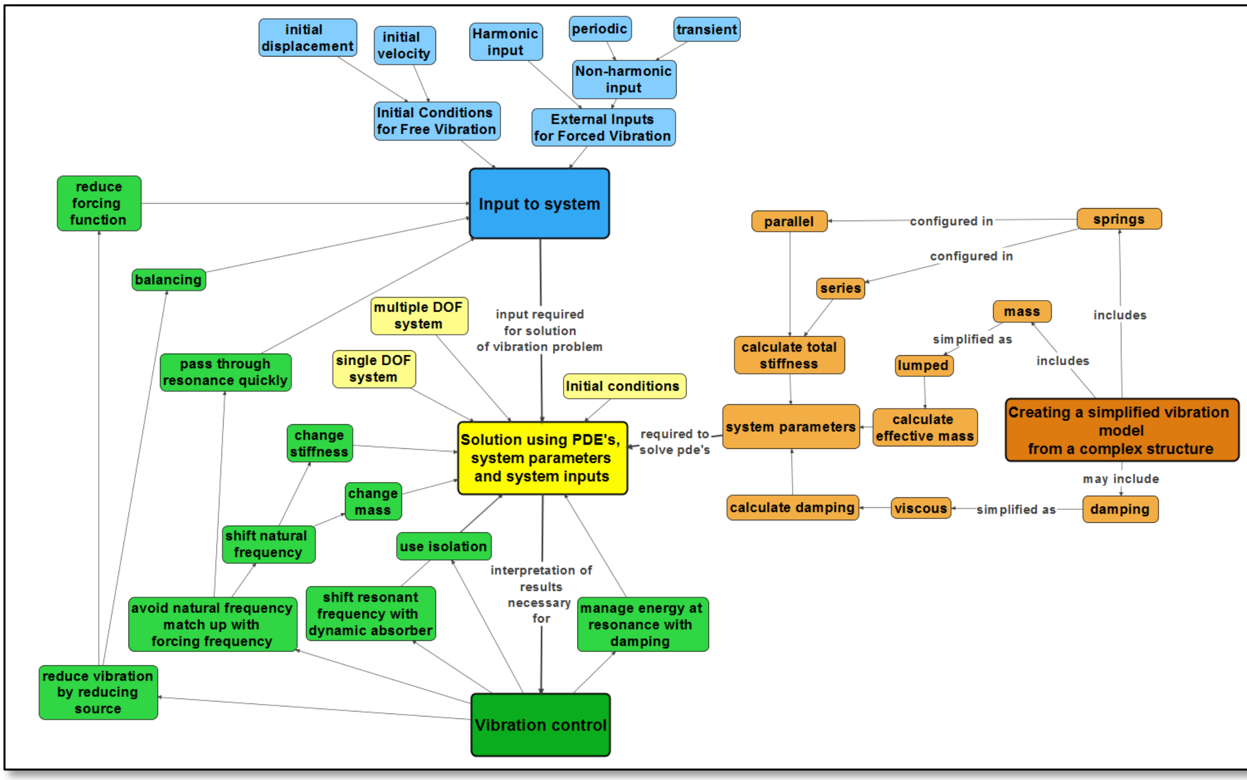

Figure 2: Reconfigured Vibrations Class concept map

The examination of the Figure 2 concept map led to the creation of the course objectives and priorities as shown in Table 1. This table places the learning objectives developed from examination of the Figure 2 concept map onto Wiggins and McTighe's categories of enduring understanding, important to know and do, and good to be familiar with.

The first enduring understanding content area in Table 1 represents the area that was previously passed over too quickly; the creation of simplified, abstract models that represent complex physical structures. The correct execution of this step is essential since all subsequent steps follow from this initial abstraction. Bransford, Brown and Cocking argued that problem abstraction is a valuable skill since the ability to transfer knowledge to new situations is "enhanced by instruction that helps students represent problems at higher levels of abstraction".[1]

Table 1: Learning Objectives

Enduring understandings:

Objective #1: Students will be able to create simplified, abstract models of complex physical structures that represent the vibration phenomena of concern.

Objective #2: Students will be able to describe how variables in vibration equations relate to the physical world.

Objective #3: Students will be able to describe strategies for controlling vibration and be able to explain how to modify systems to control vibration.

Important to know and do:

Objective #4: Students will be able to use the models from objective #1 to create equations that govern vibratory motion and then solve these equations.

Objective #5: Students will be able to calculate system parameters from the data for physical components.

Objective #6: Students will be able to apply Fourier analysis and superposition to vibration problems.

Objective #7: Students will be able to evaluate the effectiveness of different vibration control strategies and describe their tradeoffs.

Objective #8: Students will be able to design systems that control vibration.

Good to be familiar with:

Objective #9: Students will be able to describe NVH equipment vendor's resources and how these resources could help them solve vibration problems.

Objective #10: Students will be able to list typical vibration test equipment used in industry and the types of problems that this equipment can help them solve.

Assessment and alignment

The second step in Wiggins and McTighe's reverse design process was to align assessment with the desired learning outcomes and to determine what evidence will be accepted to demonstrate achievement of the learning outcomes. Pellegrino[6] argued that course curriculum, assessment, and pedagogy are central to the educational enterprise and that all elements of this triad should be linked and aligned to prevent incoherent educational activities. Pellegrino described alignment as occurring when "the three functions are directed toward the same ends and reinforce each other rather than working at cross-purposes."[6] To ensure alignment in the redesign of the Vibrations course, the learning objectives from Table 1 were mapped onto Bloom's taxonomy[7] as shown in Table 2.

Table 2: Bloom's Taxonomy for Vibrations

	Know	**Comprehend**	**Apply**	**Analyze**	**Synthesize**	**Evaluate**
Learning Objective	#9, #10	#2, #3, #5	#4, #6	#1	#8	#7

The mapping in Table 2 helped to maintain alignment between curriculum, assessment, and pedagogy by categorizing learning objectives. Table 2 shows that learning objectives #9 and #10 could be assessed by simple quizzes, but learning objective #8, that students will be able to design systems that control vibration, required the students to design a vibration control system. The assessment and pedagogical approach for learning objective #8 was therefore best served by including a semester design project.

Pellegrino[4] also argued that assessment was a process of reasoning from evidence and that both observation and interpretation should be based on cognitive theories that apply to the domain specific knowledge to be assessed. Pellegrino referred to this triad as the assessment triangle. For example, Figure 3 displays the assessment triangle for the enduring understanding of vibration model creation.

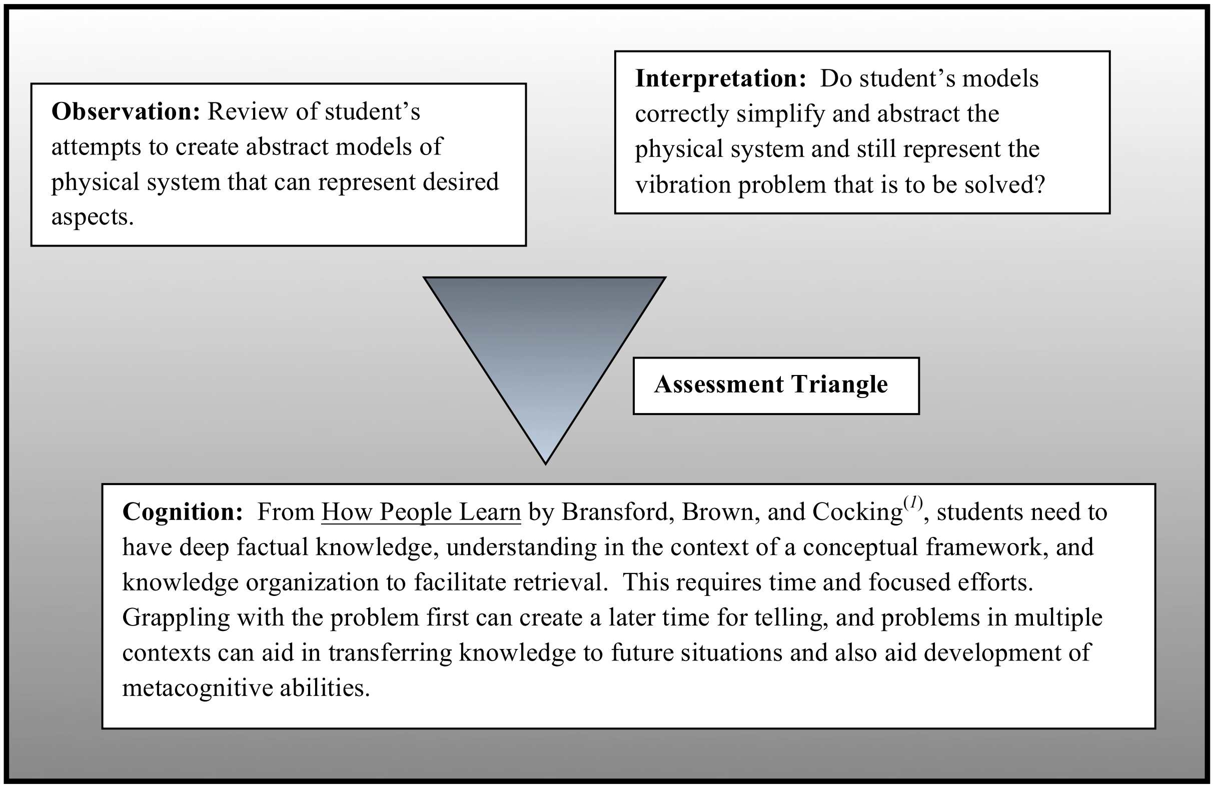

Figure 3: Assessment Triangle for the enduring understanding of model creation - Students will be able to create simplified, abstract models of complex physical structures that represent the studied vibration phenomena.

Vibrations Pedagogical revision

The third step in Wiggins and McTighe's reverse design approach was to design the learning experience. In *Making Learning Whole: How Seven Principles of Teaching Can Transform Education*, Perkins[2] argued that universities typically approach complex learning by focusing on covering "elements first" and by limiting application to "learning about". Perkins created the term *elementitis* to describe "year after year of focusing on elements with very little of the whole game"[2] and the term *aboutitis* to describe endless learning without application. While Perkins agreed that it was often appropriate to start based on elements and to learn about topics, he believed that continuing in this fashion indefinitely was damaging. Perkins also believed that elementitis and aboutitis were endemic in university settings and that students had too much material thrown at them—so much material that they never got a chance to play the whole game and put the pieces together.

This redesign of Vibrations sought to reduce elementitis and aboutitis by including a course project. The project challenged the students to design, build, and test a system to mount a video camera to a bicycle to reduce camera shake during bicycle operation, thereby requiring the students to apply vibration control theories.

Survey results

The effects of these content, assessment, and pedagogical changes were evaluated by surveying students who had taken the Vibration's class over the last five years. Since the Vibrations class was only offered in spring semesters, this five-year period included two classes of students who had been exposed to these changes and three classes of students who had been not been exposed to these changes.

The survey was sent to 54 former students from the last five years that were on record at the alumni office. After emailing the survey, it was determined that only 47 of the email addresses were still valid. Eight former Vibrations students responded to the survey yielding a response rate of 17%. Responses were split evenly between students who had and had not been exposed to the reconfigured Vibrations class.

The survey data was analyzed by coding the survey results by category and then quantitatively and qualitatively examining the results. In response to the question "Please list any ways that you have used the material covered in Vibrations since taking the class", the following categories emerged:

Used at work – 5 occurrences
Used for personal projects – 1 occurrence
Used for subsequent school projects – 1 occurrence
Not used at all – 1 occurrence

These responses were encouraging as seven out of eight responses, or about 88%, indicated that the former Vibrations students were using the material.

.

In response to the question "What would you do to make the content of Vibrations easier to understand and/or more memorable?", the following three categories emerged:

More class projects – 2 occurrences
More homework problems – 1 occurrence
More industry examples – 5 occurrences

Some notable comments from the former students to this question were:

> "I think Vibrations is a very hard concept, and the book was not that helpful. More hands on learning would help to make it easier to understand and more memorable."
>
> "I most remember anecdotes that you used in class. These usually stir memory of the principles you were explaining."
>
> "Incorporate more analysis of vibrations via electronic methods (shaker tables, computers, etc.). Conceptual is good, but is rarely used in the "design and build" industry."
>
> "The equations needed to be easier to understand. I was lost in how to set them up in order to get useful results."
>
> "More real world examples. The bike camera isolation project sounds like it would have been a cool project to work on."

In response to the question: "If you had the bike camera project assigned to you, please comment as to whether or not the project helped your understanding of the Vibrations material." yielded the following answers:

> "Yes. Anything in real life is a good thing. Hands on projects and things are what I love. These are the times we get to 'play' and see real life applications to our math and paperwork we have done."
>
> "Yes, but, due to assembly our design was hard to get accurate results. Something slightly easier to achieve good results would be helpful."
> "I attempted to use a tuned damper, and I remember it was very difficult to tune."
>
> "Yeah, it helped me a lot to understand the basic principles of the course and its calculation and forming of charts."

In summary, the survey results supported the inclusion of a class project and reinforced the value of Wiggins and McTighe's reverse design approach.

References

1. J. D. Bransford, A. L. Brown, R. R. Cocking, How people learn. (2000).
2. D. N. Perkins, *Making learning whole: How seven principles of teaching can transform education*. (Wiley.com, 2010).
3. J. McTighe, G. Wiggins, Understanding by design. (1999).
4. J. W. Pellegrino, N. Chudowsky, R. Glaser, *Knowing what students know: The science and design of educational assessment*. (National Academies Press, 2001).
5. G. P. Wiggins, J. McTighe, *Understanding by design*. (ASCD, 2005).
6. J. W. Pellegrino, Rethinking and redesigning curriculum, instruction and assessment: What contemporary research and theory suggests. *commissioned by the National Center on Education and the Economy for the New Commission on the Skills of the American Workforce*, (2006).
7. Bloom, Engelhart, Furst, Hill, Krathwohl, Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. (1956).