AC 2012-4952: ASSESSMENT OF A WELL-DESIGNED MECHANICAL VIBRATIONS COURSE

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Mysore Narayanan obtained his Ph.D. from the University of Liverpool, England in the area of electrical and electronic engineering. He joined Miami University in 1980 and teaches a wide variety of electrical, electronic, and mechanical engineering courses. He has been invited to contribute articles to several encyclopedias and has published and presented dozens of papers at local, regional, national, and international conferences. He has also designed, developed, organized, and chaired several conferences for Miami University and conference sessions for a variety of organizations. He is a Senior Member of IEEE and is a member of ASME, SIAM, ASEE, and AGU. He is actively involved in CELT activities and regularly participates and presents at the Lilly Conference. He has been the recipient of several Faculty Learning Community awards. He is also very active in assessment activities and has presented more than thirty five papers at various assessment institutes. His posters in the areas of assessment, Bloom's Taxonomy, and Socratic Inquisition have received widespread acclaim from several scholars in the area of cognitive science and educational methodologies. He has received the Assessment of Critical Thinking Award twice and is currently working towards incorporating writing assignments that enhance students' critical thinking capabilities.

Assessment of a well-designed Mechanical Vibrations Course

Abstract

Most of the time, mechanical vibration poses a highly undesirable aspect in the area of manufacturing. This is because vibrations waste energy and create unwanted noise. In addition, vibrations may cause unnecessary wear and tear on bearings and foundation structures of large equipment such as gasoline and diesel engines. Vibrations are frequently encountered with turbines and electric motors and generators. Therefore it is very important that manufacturing engineers study, in depth the topic of mechanical vibrations. According to the laws of physics, sound and vibrations are very closely related. In other words, if one's objective is to reduce noise, one has to reduce vibrations. In this presentation the author provides guidelines towards generating a mathematics based curriculum in the area of mechanical vibrations. He draws from his experience and also from various textbooks and relates them to the curriculum that is normally encountered in a mechanical engineering program. He also provides outlines for conducting assessment using appropriate data. This assessment data will be extremely useful for implementing Continuous Quality Improvement. He also provides examples and analyzes assessment data.

Introduction

Importance of mechanical vibrations in the field of engineering is all too well known. Most engineers are fairly knowledgeable about the plenty of disadvantages vibrations pose. However, there are a few merits of mechanical vibrations as well. This is indeed stirring up engineers worldwide to concentrate their efforts to make advantages use of vibrations, while curtailing its disadvantages. For example, a vibrating string instrument like a guitar or a sitar can provide melodious music. Vibration is commonly used when density separation techniques are employed. Vibrating sieves are widely used in industry. One may prefer to have one's cell phone in a *vibrating* mode. Vibration is an integral and indispensible part of almost all reciprocating and rotating machinery. When vibration is undesirable, like in the case of an old engine or as in the case of an earthquake, one has to devise ways of controlling it or eliminating it completely if possible. Vibration can be controlled only when the engineer acquires complete knowledge of its source and cause. Engineering instrumentation and measurement is the key to controlling mechanical vibrations.

Mechanical vibrations and structural vibrations are of great interest and extreme importance to a design engineer. For example, the vibrations caused by an improperly installed washing machine or an electric drier in the basement of a house can cause eventual damage to the machinery itself. Furthermore, these vibrations can set into the motion the floor and walls of the basement of the dwelling. This may ultimately result in structural failure. These vibrations are obviously perceptible as well as audible and as such extremely annoying. Mechanical vibrations are defined as *oscillations that repeat within a time period.* Some of the commonly discussed classes of vibration are:

- Free or undisturbed vibrations
- Forced or disturbed vibrations
- Damped vibrations
- Undamped vibrations
- Nonlinear vibrations
- Linear vibrations
- Random or unpredictable vibrations
- Deterministic vibrations

The study of vibrations in complex structures has been a hot topic during recent times and research work funded by the Marshall Space Flight Center in Huntsville, Alabama focuses on microgravity equipment vibrations as well. Research work currently being performed at Clarkson University in Potsdam, New York also documents and shows much interest in using the microgravity condition for scientific experiments. The bandwidth of some of the excitations may be from very low frequency, less than 30 Hz. The very low frequency accelerations are in the microgravity range whereas the accelerations above 0.01 Hz are several orders of magnitude above the microgravity level. Sophisticated laboratory experiments assisted by computer simulations and are being used to examine and understand the situation in greater depth. The ultimate objective is to provide the needed understanding and to test the effectiveness of vibration control strategy.

(http://web.clarkson.edu/projects/)

Several studies about human responses to mechanical vibrations have been carried out at the Federal University of Minas Gerais in Brazil, and various other universities. These involve whole-body vibration and vibration applied perpendicularly to the tendon or muscle. Researchers have also conducted studies to verify the effects of mechanical vibration applied in the opposite direction of muscle shortening on maximal isometric strength of the flexor muscles of the elbow due to neural factors (Silva, Couto & Szmuchrowski, 2008). These data suggest that training with vibrations applied in the opposite direction of muscle shortening enhances the mechanism of involuntary control of muscle activity and may improve strength in untrained males.

Life-long Learning

One has to appreciate the fact that students need motivation to become lifelong learners. Therefore it is the responsibility of the instructors in higher education to develop, generate, create and establish an environment in which students not only obtain necessary background knowledge, but also become enthusiastic in becoming lifelong learners (Deemer, 2003). Researchers have also concluded that students are indeed focused on learning the subject matter than on just obtaining impressive grades (Pollio and Beck, 2000). Regardless, students also admit that grades are extremely important for them, keeping in perspective, their future career goals. Researchers have also concluded that effort and capability are closely related and there are plenty of recorded studies that correlate strong motivation to cognitive engagement creative learning (Pintrich, 2000, Ames and Archer, 1988).

Educational psychologists have argued that one may want to focus on solving certain specific problems in a particular type of classroom so that teaching is less emphasized compared to a productive learning environment (Aspy, 1970). Scholarly teaching not only helps instructors experiment their innovative ideas, but also helps the students to focus more on the process of learning through a discovery approach (Broadley, Broadley, Slater, & Suddaby, 2000). This may appear like conflicting interests, however one should appreciate the fact that the goals and objectives of students as well as the instructors still remain the same, namely the importance of emphasizing learning in the classroom environment. Students should have a desire to accomplish a better performance on the learning modules that promote deeper processing techniques and challenges (Graham & Golen, 1991).

Reuben Tozman is the President and founder of a rapidly growing learning services company, edCetra Training. According to Reuben Tozman *"Schemas are the evolution of the information mapping process and the culmination of the information gathered to date into a structured model that imposes itself on the design process."* Tozman also indicates that *Schemas* impose structure using organizational taxonomy, ensure consistency within an organization, and save time and money. In other words, *Schemas* are a set of rules for designing instruction that delivers the right information to the right people in an appropriate way. When the author tried to develop a mechanical vibrations course, he tried to incorporate one of Reuben Tozman's ideas in to his classroom curriculum design. This is because Reuben Tozman says that *"Schemas both limit and empower a designer to construct learning programs that are standardized throughout an organization."* Having everybody using the same set of rules will save lot of classroom time and effort. Schemas do not dictate how information looks; schemas dictate how information is broken down according to approved standards within an organization. The above three paragraphs were previously published by the author during 2010 ASEE conference proceedings in Louisville, Kentucky. They have been reproduced here for sake of clarity and completeness.

Basic Structure

It is a widely accepted fact that certain needed content material is essential in any course that deals with the fundamentals of mechanical vibrations. One assumes that the course is taught at a junior or senior level in a four-year engineering program. This ensures that the students have had adequate background in Physics and Mathematics, including differential equations. Hopefully one expects that the students are exposed to feedback control system techniques as well. Given the fact that the students know how to use MATLAB and that they do understand what a *simple harmonic motion* is, one proceeds to build on the knowledge base that the student already possesses. Given below is a brief list of topics that may include, in no specific order.

1. A quick review of units and dimensions.
2. Stress the importance of linear algebra in engineering design methodologies. This should include a discussion of matrices, matrix manipulation and determinants.
3. A refresher course in the area of first and second order differential equations and various trigonometric and other mathematical relationships.

4. A brief outline as to the utilization of Laplace transforms for solving differential equations.
5. Fundamentals of beam deflection, bending moment and shear force diagrams.
6. Fundamentals of mechanical vibrations …. An introduction.
7. Harmonically excited vibration systems.
8. Natural frequency and related topics.
9. Single degree of freedom vibration systems.
10. Two degree of freedom vibration systems.
11. Multiple degree of freedom vibration systems.
12. Finite element analysis.
13. Nonlinear vibration.
14. Random vibration.
15. Forced vibrations.
16. Vibration control.
17. Vibration analysis.
18. Vibration measurement.
19. Numerical methods.
20. Miscellaneous topics.

Methodology and Implementation

The students taking a course in mechanical vibrations are juniors or seniors who have already completed two semesters of calculus. They also possess adequate knowledge of solving differential equations. In addition, they will have taken a course in *Advanced Engineering Mathematics* wherein surface integrals and volume integrals are discussed in depth. They have an understanding of *Gradient, Divergence and Curl.* They also have adequate background of linear algebra. Furthermore, these students were first provided with a general background of partial differential equations. Later, the students were also introduced to basic principles of vector calculus such as dot products and cross products. They also have had lectures on Buckingham Pi Theorem, Gauss' Theorem, Green's Theorem and Stokes' Theorem.

The principle is to provide the students with several 50-minute lectures pertaining to above-mentioned topics. In addition, several worked out examples must be given to the students by means of handouts. The instructor must then focus his attention on assessing and documenting the importance of selected topics in the mechanical vibrations course. The students must be quizzed on selected topics in a 50-minute examination.

The author likes to acknowledge with thanks the importance of Washington State University's Critical Thinking Rubric. This rubric has played a very important role in conducting assessment. The author has used this rubric in several of his publications and this rubric is shown in Appendix A.

The principle here, again is not to assign individual grade points. Instead, grading must be holistic. The author also recognizes that the complexity of each topic may pose some special problems for any instructor. Furthermore, each instructor's delivery style is different. It is also possible to arrive at two different sets of data for the same subject and topic. There are multiple variables, such as instructor delivery styles, diverse student body, different mathematical background and varied fundamental knowledge (Narayanan, 2007, 2009, 2010 & 2011).

Analysis

Once the course has been approved and implemented, assessment analysis can be carried out using Washington state university's critical thinking rubric. An example of what assessment may look like has been shown Appendix B. The assessment matrix utilizes a **5** point likert scale. A score of **5** may indicate that students have understood the content at the desired level. A score of **1** may be indicative that the instructor has to put in much more effort to communicate at the required level with the student body.

The bar chart is fairly self-explanatory. A detailed discussion is not included because this is only a *hypothetical case.* Referring to the bar chart shown in Appendix B, one may draw these conclusions.

A quick review of units and dimensions has recorded a score of **5** indicating that the students have understood the material at the desired level. Beam deflection, bending moment and shear force diagrams also has recorded a score of **5.** The instructor may want to challenge the students more in these areas.

A score of **4** has been recorded for the following six areas. This shows that the students have gained adequate knowledge of the content, however, the instructor should make efforts so that this category can record the maximum possible of score of **5.**

Linear algebra, matrices & determinants

First and second order differential equations

Harmonically excited vibration systems

Single degree of freedom vibration systems

Multiple degree of freedom vibration systems

Miscellaneous topics

A score of **3** has been recorded for the following five areas. This shows that the students have difficulty in understanding the content. Therefore, the instructor should make efforts so that this category can record at least an acceptable score of **4.**

Fundamentals of mechanical vibrations

Natural frequency and related topics

Two degree of freedom vibration systems

Random vibration

Vibration control

A score of **2** has been recorded for the following six areas. This shows that the students have not understood the material at the desired level. The instructor should revisit and revise his educational methodologies. These are essential topics and the students should have an adequate understanding at least. This category must record at least an adequate score of **3.**

Laplace transforms, solving differential equations

Finite element analysis

Nonlinear vibration

Forced vibrations

Vibration analysis

Numerical methods

Conclusions

In conclusion, the author would like to repeat and state that *Washington State University's Critical Thinking Rubric* has proved to be extremely valuable in documenting the effectiveness of systematic use of assessment methods. By choosing different topics and separate characteristics, an instructor can assess any area of mechanical vibrations using a learning paradigm approach as suggested by the various scholars and researchers.

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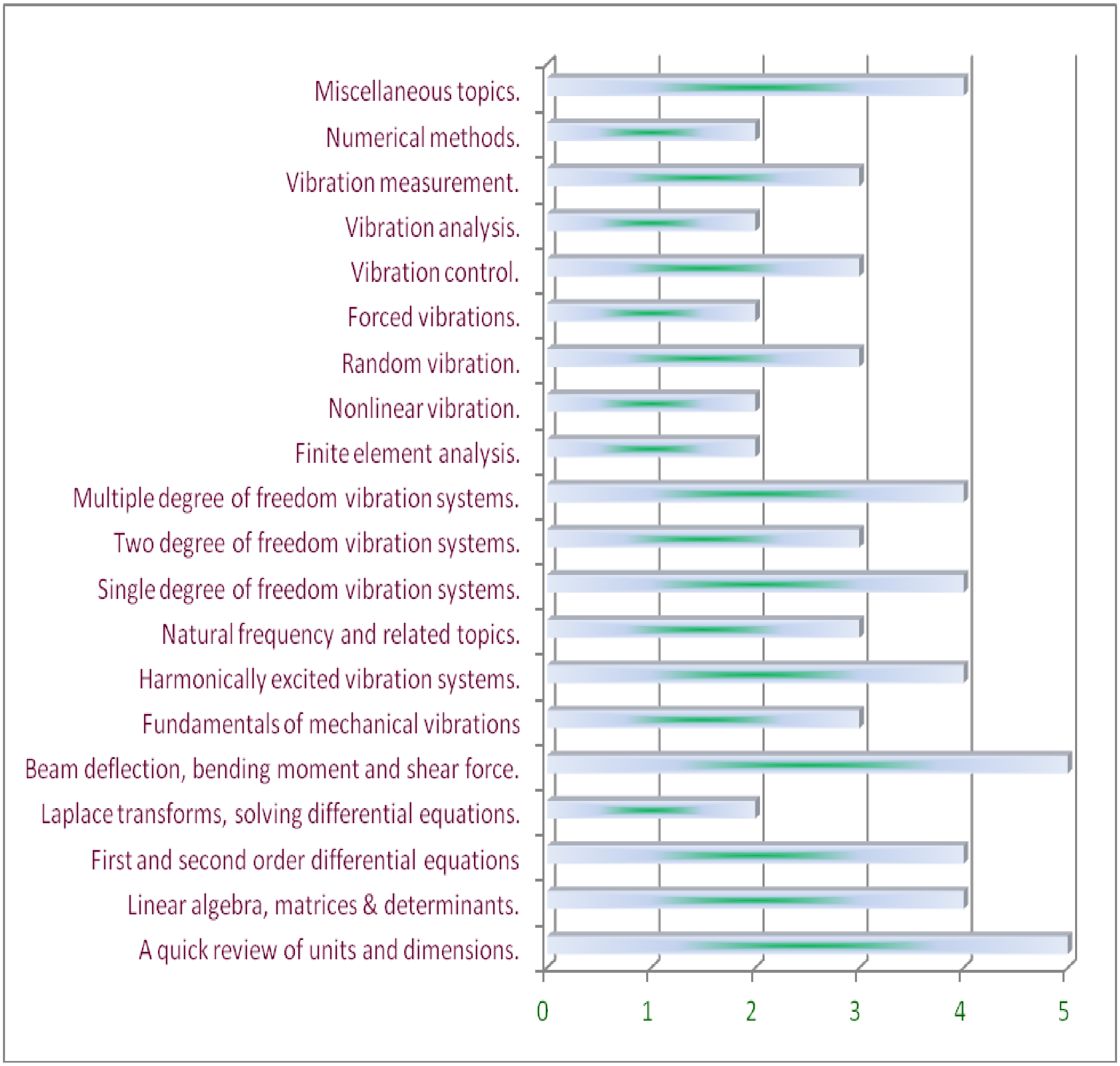
APPENDIX A : Critical Thinking Rubrics (Courtesy of W.S.U., Pullman, WA)

Score	Rubrics based on Likert Scale	
5	Has demonstrated excellence. Has provided documentation. Evidence of critical thinking ability. Very good performance	Has analyzed important data precisely. Has answered key questions correctly. Has addressed problems effectively. Has evaluated material with proper insight. Has used deductive reasoning skills. Has used inductive reasoning skills. Has employed problem solving skills. Has discussed consequences of decisions. Has been consistent with inference.
3	Has demonstrated competency. Adequate documentation. Critical thinking ability exists. Acceptable performance.	Data analysis can be improved. More effort to address key questions. Need to address problems effectively. Expand on evaluating material. Improve deductive reasoning skills. Improve inductive reasoning skills. Problem solving skills need honing. Must discuss consequences of decisions. Has been vague with inference.
1	Poor, unacceptable performance. Lacks critical thinking ability.	Absence of analytical skills. Answers questions incorrectly. Addresses problems superficially. Lacks documentation. Inability to evaluate material. Shows no deductive reasoning power. Inductive reasoning power nonexistent. Poor problem solving skills Unaware of consequences of decisions. Unable to draw conclusions.

Source: Critical Thinking Rubric, Washington State University, P.O. Box 644530, Pullman, WA 99164 - 4530 USA.(2005) http://wsuctproject.wsu.edu/ctr.htm

Appendix B: An example of what assessment bar char may look like.



References:

Ames, C., & Archer, J. (1988). *Achievement goals in the classroom: Students' learning strategies and motivation processes.* Journal of Educational Psychology, 80, 260-267.

Aspy, D. N. (1970). *Educational psychology: Challenged or challenging?* Journal of Teacher Education, 21, 5-12.

Astin, A. (1977). *Four critical years.* San Francisco: Jossey-Bass Publishers.

Barrows, Howard S. (2000). *Problem-Based Learning Applied to Medical Education.* Springfield, IL: Southern Illinois University School of Medicine.

Boud, D., Feletti, G. (1991). *The Challenge of Problem-based Learning.* United Kingdom. London: Kogan Page Publishers.

Boylan, H. (1988). *The historical roots of developmental education. Part III.* Review of Research in Developmental Education, 5 (3).

Boylan, H., Bonham, B., & Bliss, L. (1992). *The impact of developmental programs.* Research in Developmental Education, 9 (5).

Boylan, Hunter R. (2001). *Making the Case for Developmental Education.* Research in Developmental Education, 12 (2).

http://www.umkc.edu/cad/nade/nadedocs/hbcase95.htm

Brier, E. (1984). *Bridging the academic preparation gap: A historical view.* Journal of Developmental Education, 8 (1), 2-5.

Broadley, K., Broadley, G., Slater, G., & Suddaby, G. (2000). *Promoting and improving teaching: Strategies approaches and practical ideas.* Journal on Excellence in College Teaching, 11, 97-116.

Chickering, A. (1969). *Education and identity.* San Francisco: Jossey-Bass Publishers.

Deemer, Sandra A. (2003). *Using Achievement goal Theory to Create Motivating Learning Environments.* Journal on Excellence in College Teaching, 14 (1), 5-19.

Graham, S., & Golan, S. (1991). *Motivational influences on cognition: Task involvement, ego involvement, and depth of information processing.* Journal of Educational Psychology, 83, 187-194.

Hawkins, P., & Winter, J. (1997). *Mastering change: Learning the lessons of the enterprise in higher education initiative.* London, United Kingdom: Department for Education and Employment.

Hodgkinson, H. (1985). *All one system: Demographics of education, kindergarten through high school.* Washington, D.C.: Institute for Educational Leadership.

Hodgkinson, H. (1993). *Southern crossroads: A demographic look at the southeast.* Tallahassee, FL: Southeastern Regional Vision for Education.

Marchese, Theodore J. (1991). *TQM reaches the academy.* AAHE Bulletin, 44, 3-9.

Marchese, Theodore J. (1997). *The new conversations about learning. In Assessing Impact: Evidence and Action.* Washington DC: AAHE: American Association for Higher Education.

Midgley, C. (2002). *Goals, goal structures, and patterns of adaptive learning.* Mahwah, NJ: Erlbaum Associates Publishers.

Narayanan, Mysore. (2004). *What is Assessment ? A Different Point of View.* The 16th Annual Lilly-West National Conference, March 19 & 20, 2004 at the Kellogg West Ranch at Cal Poly Pomona, California. Session No. 2E.

Narayanan, Mysore. (2004). *A Learner-Centered Student Course Portfolio.* 2004 ASME Heat Transfer/Fluids Engineering International Conference, Westin Charlotte & Convention Center Charlotte, North Carolina. July 11–15, 2004. HT – FED04 – 56861. Track 1–TOC. p 1-9.

Narayanan, Mysore. (2005). *Assessment and Technology Enhanced Learning.* Proceedings of the ASEE Annual Conference and Exposition, Portland, OR. June 11–15, 2005. Paper # AC 2005-45. Session # 1660.

Narayanan, Mysore. (2006). *An Effective Assessment Rubric Based on the Taxonomy Triangle of Benjamin Bloom"* The 18th Annual Lilly-West National Conference, March 17 & 18, 2006 at the Kellogg West Ranch at Cal Poly Pomona, California.

Narayanan, Mysore. (2008). *Assessment of Air Quality Education using VARK Learning Styles.* World Environmental and Water Resources Congress 2008 - Ahupua'A. Honolulu, Hawaii. pp. 1-6, pp. 1-6, doi 10.1061/40976(316)629.

Narayanan, Mysore. (2007). *Assessment of Ethics Modules in an Engineering Curriculum.* ASEE 114th Annual Conference and Exposition, Honolulu, HI. June 24–27, 2007. Paper # AC 2007-14. Teaching Ethics – II. Session # 3440. Wednesday, 27th June 2007. 12:30 – 2 PM.

Nickerson, R.S., Perkins, D.N., Smith, E.E. (1985). *The Teaching of Thinking.* Hillsdale, New Jersey: Lawrence Erlbaum Associates Publishers.

Pintrich, P. R. (2000). *An achievement goal theory perspective on issues in motivation terminology, theory, and research.* Contemporary Educational Psychology, 25, 92-104.

Pollio, H. R., & Beck, H. P. (2000). *When the tail wags the dog: Perceptions of learning and grade orientation in and by contemporary college students and faculty.* Journal of Higher Education, 71, 84-102.

Rowntree, D.(1977). Ass*essing Students: How Shall We Know Them?* New York: Harper and Row Publishers.

Sedlacek, W. (1987, November). *Black students on white campuses: 20 years of research.* Journal of College Student Personnel, 484-495.

Silva, H. R., Couto, B.P., Szmuchrowski, L.A. (2008) *Effects of mechanical vibration applied in the opposite direction of muscle shortening on maximal isometric strength.* Journal of Strength and Conditioning Research. 2008 July 22(4) 1031-6.

Wilkerson, L., & Gijselaers, W.H. (Eds.) (1996). *Bringing Problem-Based Learning to Higher Education: Theory and Practice.* San Francisco: Jossey-Bass Publishers

Woods, Donald R. (1994). *Problem-based Learning: How to Gain the Most from PBL.* Hamilton, Ontario, Canada: Donald R. Woods Publishers.