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Runge-Kutta Algorithm and Assessment

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DR. 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.

Abstract

In this paper, the author stresses the importance of certain sophisticated mathematical techniques that undergraduate students utilize to analyze and solve a certain specific engineering problem such as the design of a Suspension Bridge or the construction of a High Voltage Transmission Tower. The importance of a fourth order Runge Kutta Algorithm technique, the need for Newton Raphson Method and the properties of a Catenary Curve are stressed in this senior level engineering technology course. The Runge Kutta technique is utilized to solve a design problem in Hydrology and Fluid Mechanics as well. The importance of Hyperbolic Functions is stressed in Catenary Curve Calculations. Once the foundation has been established, the students can be provided with rigorous analytical methods concerning the mathematical aspects of Fourier Series, Fourier Integral, Fourier Transform, Laplace Transform, Numerical Analysis, Regression Analysis etc. However, in this paper, the author mainly focuses on student learning accomplishments in the area of Advanced Engineering Mathematics. He also analyzes and documents assessment data that he has collected.

Introduction

Engineering educators have been utilizing real-world problems as a stimulus for student learning and this methodology is not at all new and has been in practice for a very long time. Scholars have defined Problem-based learning as minds-on, hands-on, focused, experiential learning (Wilkerson & Gijselaers, 1996). Instructors are considered to serve as problem solving colleagues assigned with the responsibility of promoting interest and enthusiasm for learning A problem-based curriculum is significantly different from the traditional discipline centered curriculum (Woods, 1994).

Instructors are also encouraged to act as cognitive coaches who can nurture an environment that can support open inquiry (Barrows, 2000). It is important that the aims and objectives of problem-based learning are reflected in every aspect of the learning environment created. Problem-based curriculum should document accomplishments at the upper levels of Bloom's Taxonomy Triangle (Boud & Feletti, 1991). Learning is strongly *affected by the educational climate* in which it takes place: the settings and surroundings, the influences of others, and the values accorded to the life of the mind and to learning achievements.

Furthermore, learning requires *frequent feedback* if it is to be sustained, *practice* if it is to be nourished, and *opportunities to use* what has been learned. Much learning takes place *informally and incidentally*, beyond explicit teaching or the classroom, in casual contacts with faculty and staff, peers, campus life, active social and community involvements, and unplanned but fertile and complex situations. The great success of Barr and Tagg’s learning paradigm article provides us with a valuable insight about the kind of change that is urgently needed in University Higher Education (Barr & Tagg 1995). The author has previously utilized these ideas in several of his ASEE publications and presentations (Narayanan, 2007 & 2009).

Assessment

Scholars agree that *Assessment* is a process in which rich, usable, credible *feedback* from an act of teaching or curriculum comes to be *reflected* upon by an academic community, and then is *acted* on by that community, a department or college, within its commitment to get smarter and better at what it does (Marchese, 1997, page 93). The National Research Council says that High-quality Mathematics Assessment must focus on the interaction of assessment with learning and teaching.

As an integral part, assessment provides an opportunity for teachers and students alike to identify areas of understanding and misunderstanding. With this knowledge, students and teachers can build on the understanding and seek to transform misunderstanding into significant learning (N.R.C., 1993). Assessment as *'learning'* is not a third-party research project or someone's questionnaire; it must be viewed as a community effort or nothing, driven by a faculty's own commitment to reflect, judge, and improve (Narayanan, 2007 & 2009).

The author has tried to follow such a philosophy while gathering data for this project. In this presentation the author provides some guidelines for conducting assessment of certain topics in the area of Advanced Engineering Mathematics. He also utilizes the principles outlined by a variety of scholars that include Theodore Marchese, Howard Gardner, Benjamin Bloom, Edgar Dale, Hunter Boylan, Walter Barbe, Robert Barr & John Tagg, Ernest Pascarella & Patrick Terenzini, Neil Fleming & Colleen Mills.

Scholars in the area of cognitive science and educational psychology have identified four features that clearly separate a problem based curriculum from a traditional, topic-based curriculum. These are listed below (Nickerson, et. al. 1985). The author has used these ideas in several of his ASEE publications successfully. Part of it has been reproduced here for sake of clarity and completeness.

Four Features of Learning

1. Learning must be cumulative:

The subject matter is not learned by the student in great depth at one long stretch. On the contrary, the topics are introduced gradually and repeatedly. Furthermore, the level of complexity of subject matter should increase with the progression of time. This is very much true in the area of Advanced Engineering Mathematics. For example, students understand the principles of integration initially. Later on, they proceed to learn about Contour Integral, Surface Integral and Triple Integrals.

2. Learning must be integrated:

The subject matter is must not introduced with a stand-alone approach. Topics are always discussed as the correlate to a real world problem. In other words, the students clearly understand the need for rigorous mathematical analysis that is necessary for emphasizing engineering design. For example, knowledge of Hyperbolic Functions is essential if the students are designing a structure such as St. Louis Arch.

3. Learning must be progressive:

The student's learning keeps changing continuously. Learners begin acquiring specific skills and knowledge of subject matter. As time progresses, this knowledge base is expanded and integrated with what has already been learnt. For example, students initially learn about the importance of Natural Frequency Calculations. These are the needed mathematical techniques that they subsequently utilize in the Mechanical Vibrations Course.

4. Learning must be consistent:

The learning environment created should ensure repeatability. Every learner should accomplish identical goals and educational outcomes. Individual learning styles should have no impact on the knowledge acquired. This is easily accomplished by documenting student-generated work such as homework assignments, reports, quizzes, examinations, project binders, etc.

Multiple Intelligences

Harvard University Professor Howard Gardner introduced the theory of Multiple Intelligences in 1983. Howard Gardner is the Director of Harvard Project Zero and Professor of Cognition and Education at the Harvard Graduate School of Education. He has received numerous honors and written dozens of books (Gardner, 1983). Howard Gardner was the first American to receive the *University of Louisville's Grawemeyer Award in Education.*

Dr. Howard Gardner is best known in educational circles for his theory of multiple intelligences, a critique of the notion that there exists but a single human intelligence that can be assessed by standard psychometric instruments (Gardner, 1993). Dr. Gardner suggested that the Intelligence Quotient, IQ alone should not become the primary basis for measuring human potential (Armstrong, 1993 & 1994). The author has successfully utilized these ideas in his research activities and has documented them in several of his ASEE publications and presentations (Narayanan, 2007, 2009).

Dr. Howard Gardner proposed that there are seven broad areas wherein children and adults can excel and listed them as follows:

Gardner's Theory of Multiple Intelligences

1. Word Smart: Linguistic Intelligence
2. Number Smart: Mathematical Intelligence
3. Picture Smart: Visual Intelligence
4. Body Smart: Kinesthetic Intelligence
5. Music Smart: Musical Intelligence
6. People Smart: Interpersonal Intelligence
7. Self Smart: Intrapersonal Intelligence

There is a possibility of adding three more.

8. Naturalist Intelligence
9. Spatial Intelligence
10. Existential Intelligence.

VARK Learning Styles

Neil Fleming and Colleen Mills of New Zealand suggested four modalities that seemed to reflect the experiences of the students and teachers (Fleming & Mills, 1992). VARK is an acronym that stands for Visual, Auditory, Read (includes writing), and Kinesthetic sensory modalities that humans employ for learning and processing information.

The author believes it is important to recognize other researchers who have also contributed in the area of cognitive science, educational psychology and educational methodologies. The author presented these findings at the 2009 ASEE National Conference in Austin, Texas. Part of it has been reproduced here, below for the sake of clarity and completeness (Narayanan, 2009). Regardless, we all should recognize the fact that mankind is more adaptable to ***multimodal*** learning styles.

Visual (V)

Certain groups of learners prefer when material is in a *visual* form and for these learners retention is better when they actually *see* something. This perceptual mode is referred to as *Visual* mode. It is also referred to as *Graphic* mode. Some students may learn faster when information is presented to them in the form of diagrams, tables, graphs, charts, maps, flow-charts, etc. Here one may mention the famous proverb: *A picture is worth a thousand words.*

Auditory (A)

Some other learners enjoy being *speakers* and also actively participate when others speak. This perceptual mode is referred to as *Auditory* mode. These types of students may be better at the *aural* category. Some learners may prefer being lectured to by an expert in the field. They may even enjoy listening to dialogs by a group of individuals on a radio. These types of learners like to participate in group discussions and would like to *talk things through.*

Read (R)

Academics may prefer this category of read and write. This is the third group of students who *may* be better at the *read* category. This category implies and includes *write* category as well. It is all too well known that instructors ask the students, for example: *"Read Chapter 5 from the textbook before you attend to next class meeting. We will have a lively interactive discussion."* Some other instructors ask the students to write, for example, *"A 600-word essay about Italian Renaissance."* In other words, the input to the student is text-based and the output from the student is also text-based. This perceptual mode is referred to as *Read* mode, however, it includes *Writing* as well.

Kinesthetic (K)

Some people learn only by *doing.* The author would like to include *"Tactical Learning Mode"* also in this category. These learners need *hands-on-training.* Here one may want to quote the famous phrase: *Practice Makes You Perfect.* This last, final group prefers to learn through experience. It is like performing a Ballet, or playing a Piano or building a model bridge, etc. It could also be laboratory experience, clinical experience, simulation, case studies, co-op experience, industrial internship experience, service-learning experience, practical training experience, etc. This perceptual mode is referred to as *Kinesthetic* mode.

Additional Resources

In addition to the above mentioned ideas, the author has utilized a variety of other research documentations to examine students' learning capabilities in his classroom. Some of them are listed below.

- Ohio State University's TELR
- Hunter Boylan's research documentations
- Paul Nolting's Math Study Skills
- Walter Barbe & Michael Milone's ideas about Modality
- Robert Barr & John Tagg's Learning Paradigm
- Ernest Pascarella & Patrick Terenzini's Student Engagement
- Angelo & Cross' Classroom Assessment Techniques

Implementation

At Miami University, The author utilizes a variety of instructional tools to communicate with students who may prefer to have different learning styles (Kolb, 1985). Furthermore, the author has tried to implement innovative ideas promoted by a variety of researchers and scholars into practice (Narayanan, 2009).

In addition to routinely used methodologies like traditional lectures and laboratory exercises, the author heavily promotes the implementation of 21st century modern technology. This includes, but not limited to: World Wide Web, WebEx, I.V.D.L. (Interactive Video Distance Learning) etc. Traditional Audio Visual techniques such as power point presentations, tutorials, problem-solving sessions, reflective research reports, peer group discussions, etc. also supplement student learning.

This has helped the instructor address and assess multiple intelligences and multiple dimensions of learning and thereby giving the learning environment facilitators proper guidance for moving in the *right direction.* Here, the author would like to repeat that it is important to identify the ultimate goal, which is to deliver information to students in the best possible manner that suits the receiver's optimum learning style. The author has stressed the importance of these ideas in his previous ASEE publications.

The author also recommends that students utilize the resources that are readily available at the university, such as *Library*, *Writing Center,* etc. The author would like to 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.

Procedure

At Miami University, The author did not provide the students with a questionnaire to fill out. The rationale being that *'students are exhausted in filling out forms.'* Some researchers are of the opinion: *'questionnaire-fatigue'* will result in skewed data that may lead to faulty conclusions. Therefore the assessment data was collected in an indirect manner.

The author delivered four content materials in four different modes.

Topic 1 was delivered in the traditional Lecture Format. (Aural)

Topic 2 utilized Power Point Slides and other Visual Aids. (Visual)

Topic 3 was left for the students to read, write and submit their findings. (Reading & Writing)

Topic 4 was handled like a laboratory, demonstration, group discussion, etc. (Kinesthetic & Tactical)

The four topics chosen were fairly similar in their complexity, although not exactly identical. Regardless, the instructor realizes and agrees that one topic may be tougher for the student to understand than another topic. The data collected have been tabulated, graphed and analyzed. Conclusions were drawn based on the data collected, to provide guidelines that can improve student learning.   The author has successfully utilized this technique in several of his research publications, including ASEE National Conference Presentations.

Data Collection

- Data was collected from 26 students, over a period of two semesters.
- Course: Advanced Engineering Mathematics.
- Topic Discussed and Specific Subject Matter: Runge – Kutta Algorithm.
- Seven "Characteristics" were assessed and recorded using a **5** point Likert Scale. Details are given below.
- Also assessed and recorded are the four "Delivery Styles" suggested by Fleming & Mills ***VARK*** Learning Styles. Details are provided here again, under *VARK* Data Analysis.
- The students were examined on all the above mentioned four topics. Instructor graded the test and documented his observations using EXCEL Spreadsheet format.
- The author generated two spreadsheets.   One was based on assessing student's knowledge of the subject matter.
- The other was based on assessing the impact of *VARK* learning styles.

Data Display

- The grading data obtained was tabulated using a Likert Scale. Likert Scale is shown in Appendix A.
- As mentioned earlier, grading was administered using *Washington State University's Rubric.*   This is shown Appendix B.
- Grading was holistic and qualitative.   No quantitative grade points or percentages were recorded.
- Grading was recorded based on student's perception, grasp and depth of understanding of the topic. Several *"Primary Traits"* or *"Characteristics"* were identified and assessed.

- EXCEL Spreadsheet data summary and a sample of grading scheme is shown in Appendix C.

- A Bar chart was generated based on EXCEL Spreadsheet data summary and this is shown in Appendix D.

- EXCEL Spreadsheet ***VARK*** data summary and a sample of grading scheme is shown in Appendix E.

- A Bar chart was generated based on ***VARK*** EXCEL Spreadsheet data summary and this is shown in Appendix F.

Data Analysis

Looking at the bar chart displayed in Appendix **D** one can easily see that none of the **7** characteristics assessed recorded a Likert Scale mode values of **5.**

We are trying to assess the impact of a sob–topic in the area of Advanced Engineering Mathematics. Therefore, it is probably unrealistic aspiration to achieve mode values of **5.** We should also recognize the fact that it is an undergraduate environment.

Based on the bar chart generated one can see that the three "traits"

Characteristic # 2 (General Perspective)

Characteristic # 3 (Key Assumptions)

Characteristic # 6 (Engineering Context)

all show respectable mode values of **4**.

The author is attempting to work in these areas to provide more input to students. He is trying to accomplish a mode value of **5** initially, at least in one or two characteristics. Ultimate goal is to attain a mode value of **5** in all the three.

Again, referring to the bar chart, we can see that the other four "traits"

Characteristic # 1 (Overall Knowledge)

Characteristic # 4 (Problem Correlation)

Characteristic # 5 (Mathematical Rigor)

Characteristic # 7 (Practical Applications)

all show modest mode values of **3**.

The author is in reality happy that none of the ‘traits’ assessed. Recorded a mode value of **2** or below **2.**

Regardless, modest value of **3** indicates that there is plenty of room for improvement. He is exploring ways to communicate better with the students, so that he can accomplish a mode value of at least **4** initially. Of course, the ultimate goal is to attain a mode value of **5** in all the four.

VARK Data Analysis

Looking at the bar chart displayed in Appendix **F** we see that ***Visual (V)*** and ***Kinesthetic (K)*** modes recorded Likert Scale mode values of **5.**

This is to be expected in an engineering classroom. We need to remember that we are trying to assess the impact of ***delivery styles.*** Topics in the area of Advanced Engineering Mathematics are best learnt when students actually ***see*** and ***do.***

Hands – on learning tools helped the students understand the material better. This included Power Point Presentations, EXCEL spreadsheet exercises, Problem – Solving Sessions, Practical Applications, Mathematical Analogies, etc.

Again, referring to the bar chart, we can see that ***Auditory (A)*** mode recorded a very low Likert Scale mode value of **2.** This is to be expected in an Engineering Mathematics Environment. Lectures do not help students learn Advanced Engineering Mathematics.

Finally, we see that ***Reading (R)*** and ***Writing*** recorded a modest Likert Scale mode value of **3.** This indicates that some students, who have a strong background of Engineering Mathematics are capable of “Reading” and understanding certain topics in the area of Advanced Engineering Mathematics.

Conclusions

Based on the “Data Analysis” one can easily see that there is a need for instructors to focus more on creating a dynamic classroom for the 21st Century. Here we concentrate and promote *“Learner-Centered Education.”*

This is exactly what leading researchers like Barr and Tagg promote. The great success of Barr and Tagg's article on the "learning paradigm" indicates widespread agreement about the kind of change needed in post-secondary education (Barr & Tagg, 2012)

It is not to be confused and interpreted that instructors are avoiding fundamental questions about the goals of learning.

We all recognize the fact that *disciplinary tradition* mostly dominates and determines the curriculum in a University. It is individual departments that have primary authority to establish course curriculum content.

Educational accomplishments of students should be assessed using established techniques and formats (Angelo & Cross 1993). One must recognize the fact that undue attention has been focused on inputs as a measure of educational success rather than focusing on what the students have actually learned.

Although this is a salutatory admonition, it is also true that most instructors are concerned with what students are learning, and make considerable efforts to evaluate student learning (Barr, 1995).

The discussion generated by this assessment exercise has provided the author with multiple ideas as to focus on how to achieve more efficient student learning.

APPENDIX A: Likert Scale Source: http://templatedb.me/pick/

It should be observed that the data collected are ordinal. This indicates that they have an inherent order or sequence. It must be interpreted carefully. The data is not continuous. Therefore it is not appropriate to create a histogram. Mean values do not have any meaning for interpretation.

Furthermore, *Standard Deviation* does not convey anything. The data are normally summarized using a median or a mode. The author prefers *mode* because it is considered to be the most appropriate for this type of data analysis. The data collected are normally displayed in a bar chart.

Reference: http://www.icbl.hw.ac.uk/ltdi/cookbook/info_likert_scale/

Source: Descriptive Techniques: Likert Evaluation Cookbook 2004

Four, Five and Six Point Semantic Differential Likert Scale is shown below.

1	2	3	4
Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

1	2	3	4	5	6
Extremely Dissatisfied	Very Dissatisfied	Somewhat Dissatisfied	Somewhat Satisfied	Very Satisfied	Extremely Satisfied

APPENDIX B: Five–Point Likert Scale. Rubrics courtesy of W. S. U., Pullman, WA.

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.

APPENDIX C: EXCEL Spreadsheet data summary and a sample of grading scheme

Assessing
Runge Kutta

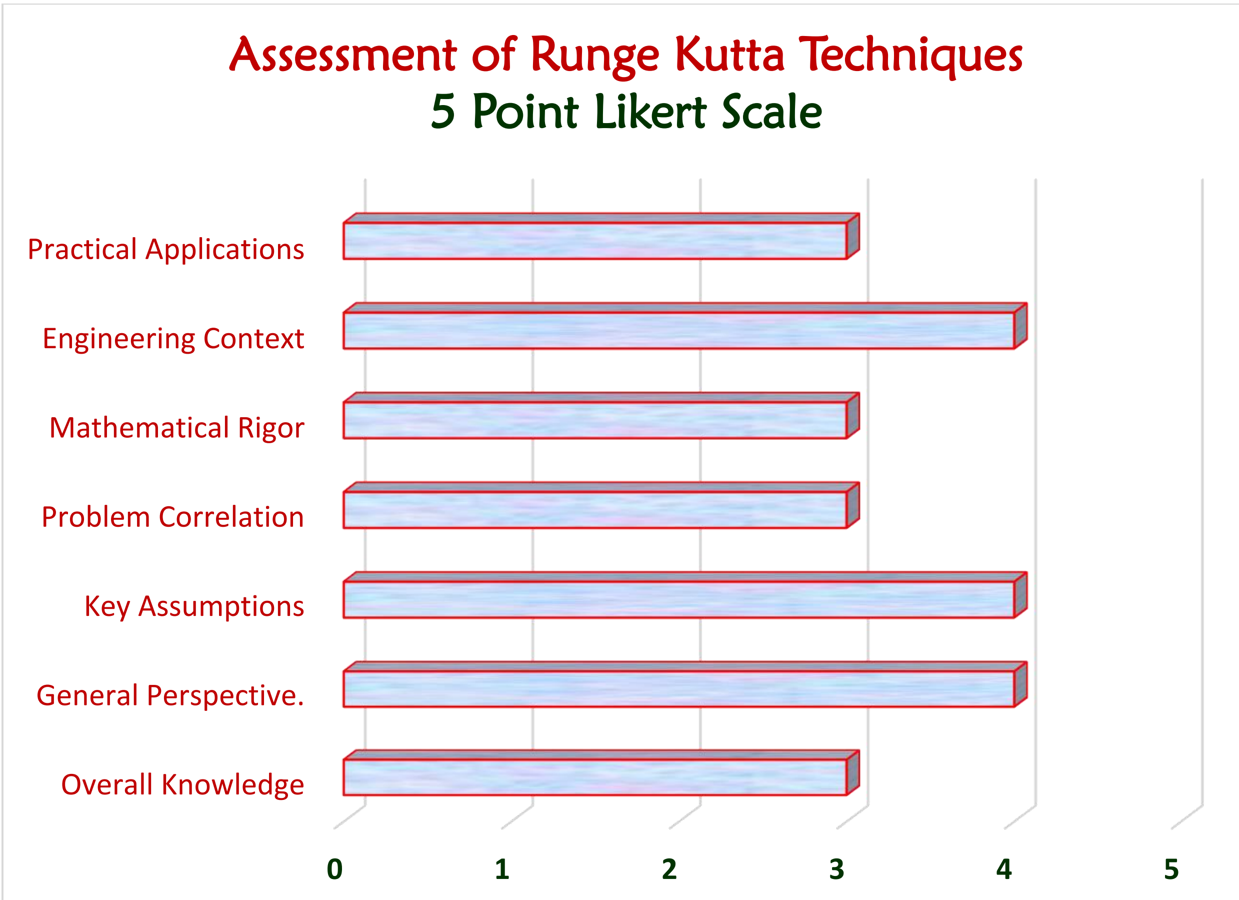
TOTAL **26** STUDENTS

CRITICAL THINKING
RUBRIC COURTESY
OF W. S. U.
PULLMAN, WA. 99164.
LIKERT SCALE WEIGHT
1 : Strongly Disagree
5 : Strongly Agree

		A	B	C	D	E		V	W	X	Y	Z	MEDIAN	MODE	AVG.
1	Overall Knowledge	4	4	3	3	4		3	3	4	3	3	3	3	3.46
2	General Perspective.	3	4	5	4	3		4	4	5	5	5	4	4	4.19
3	Key Assumptions	5	4	3	5	3		4	4	5	4	5	4	4	4.00
4	Problem Correlation	3	3	5	4	4		3	3	4	3	4	3.5	3	3.58
5	Mathematical Rigor	3	3	5	5	3		3	4	4	5	4	3.5	3	3.69
6	Engineering Context	4	4	5	5	4		4	4	5	4	5	4	4	4.35
7	Practical Applications	4	3	4	3	3		4	4	3	4	3	3	3	3.46

Data Collected by
Mysore Narayanan.

APPENDIX D: Bar chart generated based on EXCEL Spreadsheet data



APPENDIX E: EXCEL Spreadsheet data ***VARK*** grading scheme

RUNGE - KUTTA

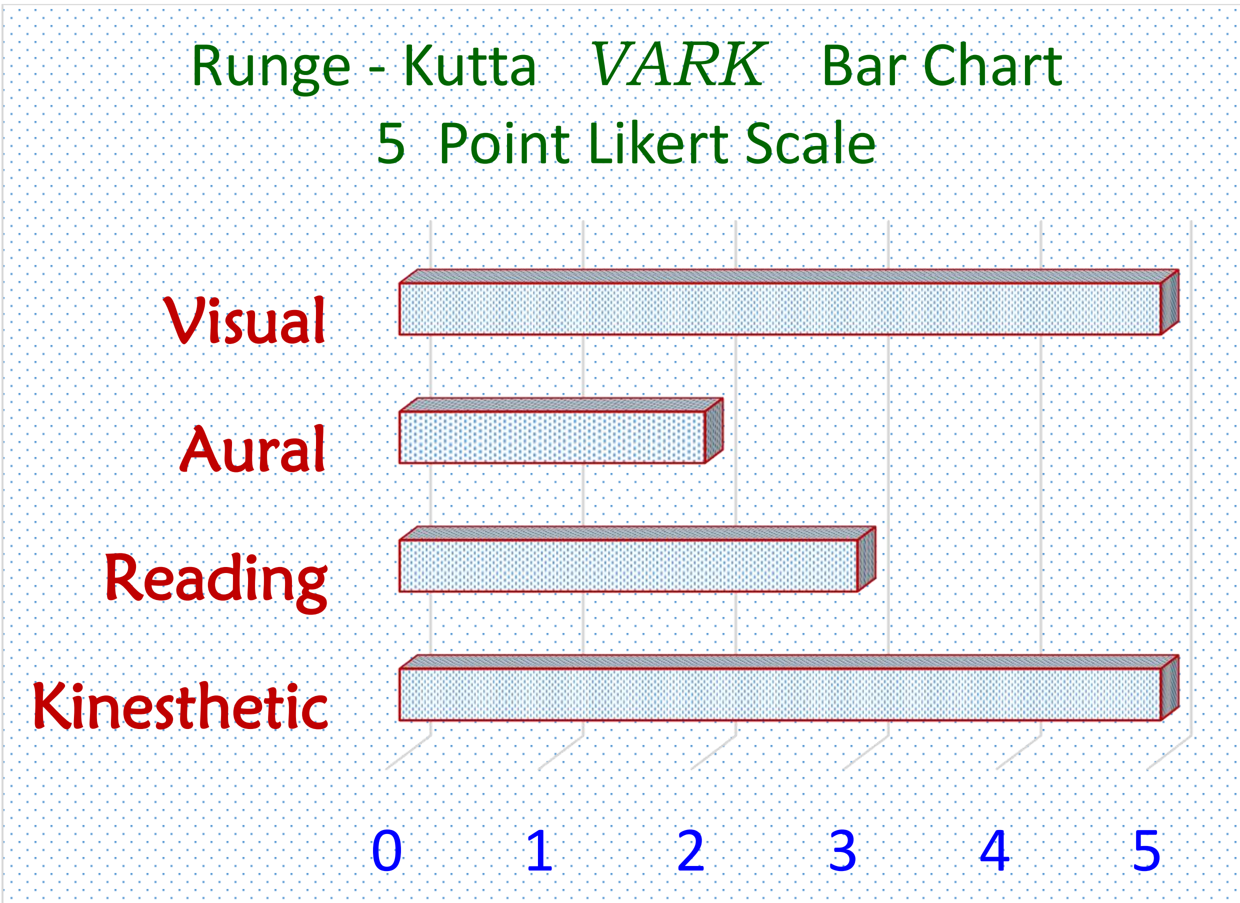
No. OF STUDENTS = 26	1	2	3	4	5	.	.	.	.	.	.	.	.	MEDIAN	MODE	AVG.

CRITICAL THINKING RUBRIC
COURTESY OF W. S. U.
PULLMAN, WA. 99164.
LIKERT SCALE
WEIGHT DISTRIBUTION :
1 : Strongly Disagree
5 : Strongly Agree

														MODE
Kinesthetic	5	4	5	5										5
Reading	3	3	3	1										3
Aural	3	2	3	3										2
Visual	4	3	5	5										5

Data Collected by
Mysore Narayanan.

APPENDIX F: Bar chart generated based on *VARK* Spreadsheet data



Source: Fleming, N. D. & Mills, C. (1992). *VARK a guide to learning styles.*

http://www.vark-learn.com/English/index.asp

References:

1. Angelo, Thomas. A., & Cross, K. Patricia. (1993). Classroom assessment techniques: A handbook for college teachers. San Francisco: Jossey –Bass.

2. Armstrong, Thomas (1993). *7 Kinds of Smart.* New York: Plume.

3. Armstrong, Thomas. (1994). *Multiple Intelligences in the Classroom.* Alexandria, VA: Association for Supervision and Curriculum Development.

4. Barbe, Walter B. & Milone, Michael N., Jr. (1980). *Modality.* Instructor, Vol. 89, pp. 44-47.

5. Barr, Robert B. & Tagg, John (1995). *From Teaching to Learning — A New Paradigm For Undergraduate Education.* Change, Vol. 27, pp. 18-25.

6. Barrows, Howard. S. (1996). *Problem-Based Learning in Medicine and Beyond: A Brief Overview. New Directions for Teaching and Learning,* Creative Education**,** 1996, 3-12. Vol.7 No.14.

7. Barrows, Howard. S. 1986. *A taxonomy of problem-based learning methods.* Medical Education, 20/6, 481–486.

8. Boylan, H. R. (1999). *Exploring alternatives to remediation.* Journal of Developmental Education, Vol. 22(3), 2-4, 6, 8, 10.

9. Boud, D. & Feletti, G. 1991. The Challenge of Problem Based learning. Kogan Page: London.

10. Dunn, R. & Dunn, K. (1979). *Learning Styles/Teaching Styles: Should They… Can They … Be Matched*. Educational Leadership, January 1979.

11. Fleming, N. D. & Mills, C. (1992). *VARK a guide to learning styles.* http://www.vark-learn.com/English/index.asp

12. Gardner, Howard (1983). *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic.

13. Gardner, Howard (1993). *Multiple Intelligences: The Theory in Practice*. New York: Basic.

14. Gardner, Howard (2000). *Intelligence Reframed: Multiple Intelligences for the 21st Century*. New York: Basic.

15. Gregorc, A. F., & Ward, H. B. (1977). *Implications for learning and teaching: A new definition for individual.* NASSP Bulletin, 61, 20-26.

16. Huba, M. & Freed, J. (2000). *Learner-Centered Assessments on College Campuses: Shifting the Focus from Teaching to Learning.* Boston: Allyn and Bacon.

17. Keefe, J. W. (1991). *Learning style: Cognitive and thinking skills.* Reston, VA: National Association of Secondary School Principals.

18. Keefe, J. W. (1988). *Profiling and utilizing learning style.* Reston, VA: National Association of Secondary School Principals.

19. Kolb (1985) *Learning Styles Inventory*. Boston, MA: TRG Training Resource Group.

20. Marchese, T.J. (1991). *TQM reaches the academy.* AAHE Bulletin, Vol. 44, pp. 3-9.

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

22. McKeachie, W.J. (1999). *Teaching Tips: Strategies, Research, and Theory for College and University Teachers.* Boston: Houghton Mifflin Company.

23. Narayanan, Mysore (2007) *Assessment of Perceptual Modality Styles.* Proceedings of ASEE National Conference, Honolulu, Hawaii.

24. Narayanan, Mysore (2009) *Assessment Based On The Principles Of Theodore Marchese*. Proceedings of ASEE National Conference, Austin, Texas.

25. Nichols, James O. & Nichols, Karen W. (2001). *The Nichols Guides to Institutional Effectiveness and Student Outcomes Assessment.* Flemington, New Jersey : Agathon Press.

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

27. Watkins, Angela Farris (2005). *Using Learning Styles in College Thinking.* Journal on Excellence in College Teaching. 16(3), 83-101.

28. Woods, D. R. *On the Learning in Problem-Based Learning.* PEDAGOGUE, 1993, 4 (2),

29. Woods, D. R., Crowe, C. M., Taylor, P. A, and Wood, P. E. *The MPS Program for Explicitly Developing Problem Solving Skill.* In 1984 ASEE Conference Proceedings. Washington, D.C.: American Society for Engineering Education, 1984.

30. Wilkerson, L., & Gijselaers, W. H. (1996). *Concluding Comments. In L. Wilkerson, & W. H. Gijselaers (Eds.), Bringing Problem-Based Learning to Higher Education:* Theory and Practice (pp. 101-104). San Francisco, CA: Jossey-Bass.

31. *http://telr.osu.edu*

32. http://wsuctproject.wsu.edu/ctr.htm

33. http://www.pz.harvard.edu/PIs/HG.htm

34. http://www.icbl.hw.ac.uk/ltdi/cookbook/info_likert_scale/