Assessment of Learning Based on the Principles of Discovery and Metacognition

Dr. Mysore Narayanan, Miami University

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 Conferences and 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 Based on the Principles of Discovery and Metacognition

Abstract

Leading educators and scholars in the area of cognitive science agree that a new paradigm for assessment called a *learning paradigm* must be generated to observe, measure, and document the success of creative, new educational methods and practices. Educators have understood the implications and importance of Bloom's Taxonomy and have tried to change their teaching styles to create a learning environment. Teachers have recognized that the students must be provided with an opportunity to develop their problem-solving skills in addition to mastering a particular body of information. Furthermore, many of our educational institutions have tried to move away from emphasizing the establishment of strong knowledge-base. The modern trend is to develop an interactive problem-solving pedagogy that encourages the development of learners' creativity, understanding, and written and oral communication skills. In a learning paradigm, it is observed that evaluation is holistic, and student success outcomes are what is measured. Many scholars have recommended and supported a *value-added* concept of education by doing assessments before, during, *and* after a course. In his book *"Learning Paradigm College"* John Tagg identifies six essential features for generating such a paradigm and provides a flexible guide and a blueprint for implementing specific changes. Other scholars have argued that achievement of educational objectives is becoming less and less measurable, whereas the need for accountability is rising to the surface more frequently. The literature supports our intuitive belief that education in a new learning paradigm will prepare students for the work ahead of them. Almost all scholars believe that in order to lead in a postmodern world, students need flexibility and problem-solving skills more than they need to master any particular body of information. In this presentation, the author attempts to provide guidelines for articulating learning objectives using a discovery approach and promotes the use of certain set of assessment methods in conjunction with appropriate rubrics that could benefit the learner as well as the instructor.

Introduction

We all agree on the fact that almost all instructors ask the students to take ownership of learning. The discovery approach used by the author tries to create and establish an innovative instructional design by marrying content with presentation style in theory as well as in practice. Utilizing real-world problems as a stimulus for student learning is not at all new and has been in practice for a very long time. Instructors have understood that scholars have defined problem-based learning as minds-on, hands-on, focused, experiential learning. Instructors have also been encouraged to act as cognitive coaches who can nurture an environment that can support open inquiry. An instructor's responsibility is to create and promote an active learning environment in which the learners themselves participate and take the center stage with the process of knowledge acquisition. Obviously this reduces students' dependence on the professor. Furthermore one must encourage the establishment of creative ways that require a deeper level of processing. The author was inspired by the unique ideas presented by these researchers and

scholars. He has tried to build on these ideas to develop a discovery approach of instructional technique.

One can conclude that learning has taken place when the instructor observes a change of learner behavior (Keefe, 1988). This learner behavior must be the result of what has been experienced in the process of instruction (Pascarella & Terenzini, 1991). It is also important to identify that in order to develop a sense of agency, student affairs professionals must possess four dimensions of learning that specify desired outcomes: cognitive competence, intrapersonal competence, interpersonal competence, and practical competence (Baxter Magolda, 2001 & 2004). The ultimate objective of discovery approach should actually be to *promote* creative learning accomplishments; not just to document teaching techniques.

Discovery approach aims to help the students to accomplish more and achieve independence instead of interdependence. Appendix A shows some to the results the author obtained during his previous research activity (Narayanan, 2012). The author has tried to successfully utilize some of the scholarly ideas of leading researchers while implementing the development of discovery approach into his current classroom activities. He presented some of these results at the 119th ASEE National Conference in San Antonio, Texas. In this, *follow-up presentation* he provides additional data that documents the importance of practicing the discovery approach.

As Director of Research and Professional Development at the Center for Critical Thinking and Chair of the National Council for Excellence in Critical Thinking, Dr. Richard Paul is an internationally recognized authority on critical thinking. Dr. Paul has written books for every grade level and has done extensive experimentation with teaching tactics and strategies, and devising, among other things, novel ways to engage students in rigorous self-assessment. The author has largely benefited from the principles of Socratic Taxonomy outlined by Richard Paul. The author has utilized these principles in his previous ASEE conference presentations. The author has also incorporated several ideas from these outlines while he experimented with the discovery approach. Richard Paul's Taxonomy of Socratic Questions is very well known and is reproduced in Appendix B (Paul, 1995).

Some researchers have also suggested that the learners should not the held responsible for poor quality (Saxe, 1990). Instead, the structure of the system and the mechanics of management must be blamed for inadequate knowledge acquisition and unacceptable performance outcomes (Senge, 1990). Researchers have further indicated that a course portfolio should be treated essentially, like a manuscript of scholarly work in progress. In other words, a course portfolio can be deemed as a work that explains what, how, and why students learn or do not learn in a course (Sims, 1992). Educators Clifford O. Young, Sr., & Laura Howzell Young of California State University, San Bernardino have argued that a new paradigm for assessment, a learning paradigm, must be constructed to measure the success of new kinds of educational practices (Young & Young, 1999).

Carnegie scholar, William Cerbin is the director of the center for effective teaching and learning, at the University of Wisconsin – LaCrosse. Cerbin, who is a professor of psychology is a widely recognized expert in the area of cognitive science and language development.

Cerbin is of the opinion that one of the most unfortunate consequences of a summative emphasis is that it inhibits open and productive discussions about teaching; in essence, it marginalizes the types of activity that could lead to better teaching (Cerbin, 1992 & 1996).

Russell Edgerton has been recognized as a leading expert on undergraduate higher education for the past thirty years and is the recipient of honorary doctor of humane letters degree from IUPUI. Edgerton indicates that teaching portfolios may contain evidence of students' learning, but such information is optional, and when included, it may be only one of many pieces of material (Edgerton, Hutchings & Quinlan, 1991). Pace University distinguished professor Peter Seldin, also supports this and stresses that the interplay between the instructor and the learner should be carefully observed and monitored (Seldin, 1991). Michael Scriven is a Distinguished Professor at the School of Behavioral and Organizational Sciences at Claremont Graduate University. Dr. Scriven says that evaluators need a few special empirical research skills along with a range of evaluative skills. The repertoire of empirical skills mainly includes those used for social science research , with its emphasis on hypothesis testing (Scriven, 2002).

All these researchers have certain specific themes in common. They all essentially stress the importance of pin pointing the problems and effectively resolving those problems at their infancy. Another similarity is to create the provision of a dynamic partnership in order to break down the barriers between the instructor and the learner. Discovery approach aims to provide appropriate guidance and relevant training, not only to the instructor, but also the student learner. These ideas lead us to the design and development of innovative instructional techniques as described below.

Assessment Implementation & Methodology

Assessment was carried out by utilizing sample quizzes, homework assignments, examinations, written essays, laboratory reports and project binders. All these documents were graded on a holistic basis using likert scale principles. Later the data collected were recorded in a tabular form using an excel spreadsheet. A matrix was generated to document grading and analysis. A sample excel table for one student's single homework assignment report is shown in Appendix E.

It is to be emphasized that it is necessary to generate a separate matrix table for *each and every* student. This is also indicative of the fact that different matrix tables have to be created for different quizzes and separate individual reports. Finally, all these data have to be consolidated into a single spreadsheet. One should recognize that this will be a fairly labor intensive, time consuming activity. However, if proper tables are generated in advance, one can fairly streamline the task on hand.

The author chose to identify and assess *Ten Primary Traits.* A separate matrix was generated to document these seven traits chosen. These traits were then further identified in the chosen quiz that was being assessed. When the quiz was graded, the author documented a likert scale grade for each of the traits that was being assessed. This has been shown in Appendix E.

Data collected from this matrix were later incorporated into a master spreadsheet and appropriate tables were generated for each student. Data from this master spreadsheet were further consolidated into a larger excel table. This was important, because such a master spreadsheet could present the researcher with a *bigger picture.* The ultimate objective was to study how the students were responding to the introduction of the *discovery approach.* The larger spreadsheet, which consolidates all the data collected is shown in Appendix F.

The author has utilized World Wide Web and Interactive Video Distance Learning extensively in addition to other teaching techniques. At Miami University, *W.W.W.* and *I.V.D.L.* actually supplement other routinely used instructional delivery techniques. Student learning is documented using a variety of audio visual techniques such as power point presentations, interactive tutorials, problem-solving sessions, written research reports, peer group discussions, poster presentations, project reports etc. The principle must always, be to utilize a variety of instructional tools to communicate with students who may prefer to have different learning styles (Kolb, 1985).

The important aspect here is to move away from a teaching paradigm to learning paradigm that is based on the discovery approach. One must remember that the ultimate goal of the discovery approach, however, is to deliver the needed information to learners in the best possible manner, that suits the *receiver's optimum learning style.*

The author also strongly recommends and encourages students to utilize the resources that are readily available at the university, such as *University Library, Divisional Documents, Departmental Research Reports, Computer Laboratory, Writing Center,* etc.

1. Discovery approach utilizes five principles and this has been documented in Appendix A.

2. Discovery Based ISD is recorded in Appendix B. According to Reuben Tozman, ***Instructional Systems Design*** *is the reference used to describe a systematic approach to the design of instruction.*

3. Analysis of data utilized *Washington State University's Critical Thinking Rubric.* This rubric has helped the instructor effectively address and assess the discovery approach and multiple dimensions of learning. The rubric has been reproduced in Appendix C.

4. The procedure followed by the author while conducting this study is shown in a symbolic form in Appendix D. The author has used a similar approach in many of his other research publications and has found the procedure to be very effective.

5. The data obtained was based on *Likert Scale* and was tabulated and recorded using an excel spreadsheet. The scale is named after its inventor, psychologist Rensis Likert and is the most widely used approach to scaling responses in survey research. Principles of *Likert Scale* are outlined in Appendix E.

6. The data collected has been tabulated using an excel spreadsheet. A sample excel table for one student's homework has been reproduced in Appendix F.

7. A consolidated excel table that was generated using data collected from various students has been reproduced in Appendix G.

8. A bar graph was generated to facilitate analysis and this is shown in Appendix H.

9. ADDIE model proposed by Walter Dick and Lou Carey has been recorded in Appendix I.

Analysis and Conclusions

The author wanted to assess seven characteristics. These were selected using a variety of criteria, such as accreditation guidelines, liberal education principles, leadership qualities, critical thinking and lifelong learning requirements. Other researchers may choose a totally different set of characteristics that could be fruitful from their point of view. Generation of a well-designed bar chart always provides the researcher with proper guidance with visual data analysis. Important strengths and weaknesses can be easily identified using the bar chart.

Referring to the bar chart shown in Appendix H, one can make these observations.

Maximum possible score of **5** on the Likert scale: Strongly Agree.

Only two categories have attained this accomplishment.

1. Course Content and Subject Matter.
2. Effective Teamwork Capabilities.

This indicates that appropriate course content material was covered at the necessary depth as well as the required breadth. It also indicates that the students are very good when working as a group in laboratory assignments as well as in design projects.

An acceptable score of **4** on the Likert scale: Agree.

Only two categories have attained this accomplishment.

1. Visual, Verbal and Vocal Communication.
2. Analyze and Interpret Scientific Data.

This indicates that the students are quite proficient in communication skills. Given proper guidance, they know how to write a report, prepare and an effective power point slide presentation. It also indicates that the students are knowledgeable about some of the scientific methods. They know how collect, document, display, interpret and analyze scientific data. One should try to achieve the maximum possible score of **5** in these categories.

A modest score of **3** on the Likert scale: Neutral.

Three categories have attained this level.

1. Desire for Life Long Learning.
2. Problem-Based-Learning.
3. Creativity in Problem-Solving

These are not adequate and the instructor has to improve these, initially to a level of **4** and ultimately to the maximum possible score of **5** on likert scale.

An unacceptable score of **2** on the Likert scale: Disagree.

Three categories have attained this level.

1. Address Societal and Global Issues.
2. Ethical and Social Responsibilities.
3. Concepts of Critical Thinking.

It is very disappointing that the students are unable to secure a good grasp of these important aspects. These are not adequate and the instructor has to improve these, initially to a level of atleast **3.** Eventually this should improve to **4** and ultimately to the maximum possible score of **5** on likert scale.

Conclusions and Continuous Improvement

The author would like to conclude that the implementation of *Discovery Approach* requires lot of effort both from the instructor as well as the learner. It is important to emphasize that the above research activity is only partially complete. The above mentioned discussions are not meant to be all conclusive. In reality, they try to provide a starting point for a newly proposed instructional activity. This paper mainly concentrates on providing the instructor with the necessary background pertaining to practicing discovery approach. It is important that pertinent theoretical aspects must be discussed during lecture meetings and problem solving tutorial sessions.

At present, the author is trying to design various hardware laboratory projects to supplement the discovery approach methodology of teaching. When student groups work on their experimental projects, they will understand and appreciate the needs and necessities of laboratory measurement techniques. They will also be able to effectively utilize and apply the knowledge gathered and gained during the lecture classes, study sessions, and in a variety of courses.

There is plenty of work to be carried out and the author tries to obtain feedback from the students and faculty at regular intervals. Washington State University's Critical Thinking Rubric has proved to be extremely valuable in documenting the effectiveness of systematic use of discovery approach. This has helped the instructor address perceptual dimensions of learning most students

acknowledge and appreciate. This will give the instructor proper guidance for moving in the right direction.

Furthermore it should be recognized that each topic or subject matter may be different and the difference may be huge and significant. Each instructor's delivery style is different and one may even arrive at two different sets of data for the same subject and topic when two different instructors are involved. The author agrees and understands that these data may *vary significantly* depending upon subject matter, instructor's delivery styles, material content, discipline, student body, etc. It is possible that *Visual* and *Kinesthetic* modes of learning may be preferred by students engineering disciplines. Such assessment data provides the instructor to make appropriate changes in the manner in which the course is developed and may necessitate changes in the *Discovery Approach of Instructional Delivery Styles.*

Acknowledgements
Dr. Mysore Narayanan is extremely grateful to the Center for the Enhancement of Learning and Teaching and Committee for the Enhancement of Learning and Teaching for granting him the award: *Faculty Learning Community to Accentuate Performance in Student-Centered Learning.* Dr. Narayanan also thanks Dr. Milt Cox, Director of Center for the Enhancement of Learning and Teaching at Miami University for his valuable suggestions and guidance. The author is extremely grateful to Dr. Gregg W. Wentzell, Managing Editor for the *Journal on Excellence in College Teaching* for his invaluable input. The author also thanks Dr. Paul Anderson, Director, *Roger and Joyce Howe Center for Writing Excellence* for his valuable guidance and encouragement

Appendix A: Five Principles of Discovery Approach

Here, the author describes how he has incorporated the principles of Socratic inquisition to assist the adaptation of the discovery approach. He also indicates how feedback data when collected systematically and analyzed critically, could provide guidelines for continuous improvement. Typically, the process of designing and developing classroom course curriculum content could be much more streamlined in a productive electronic environment. Furthermore, rapid development tools have facilitated the learners to admire and appreciate state-of-the-art technological innovations (Boyer, 1990). Discovery approach has largely benefited from the introduction of computer technology in to everyday classroom activities. The design, documentation and delivery of educational material has undergone a revolutionary process and this has proved to be very beneficial for the instructor as well as the student (Allen, et.al., 1996). Discovery approach can be successfully implemented if an instructor intelligently incorporates and follows the five principles outlined below (Narayanan, 2010 & 2012).

DEFINE: First, the instructor must clearly define the objectives of the course in question. In addition, the instructor should also provide the students with a detailed plan and the path traced for attaining these goals. Such a structure will prepare the students to admire and handle the course with great enthusiasm and creative productivity.

DESIGN: Secondly, the instructor should design *learning modules* that can generate interest and motivate the student body towards becoming metacognitive learners. In other words, one should be able manage one's own learning. Any selected module should build on the previous module, thereby creating and supporting a *value-added* mechanism. The objective is to *add* to the knowledge base the students already possess. Ultimate goal should be that students should learn, *"How to Learn."*

DEVELOP: Third, the course should be structured and developed in a systematic manner so that the learner can appreciate the fact that the course is being built on the previous knowledge acquired. For example, knowledge of physics and mathematics must be effectively utilized in a *mechanics* course. It is important to recognize that a methodical approach has always been the principle behind solid fundamental knowledge acquisition.

DEPLOY: Once the first three ideas have been secured in place, it is now necessary to implement them at the required level with appropriate advantage. Here, the instructor should utilize multiples modes of delivery techniques. Such methods have been suggested by Fleming and Mills. Lectures, Reading, Writing, Visual Aids, Tactile and Kinesthetic modes of delivery help to reach students with diverse learning skills.

DECIDE: Finally, there should be separate assessments of the course, the curriculum, the student body, the instructor and the discovery approach. In particular, the techniques used should specifically study the impact of the discovery approach on the learning environment. It is important to conduct separate assessment of all the above-mentioned five. Once the five sets of data are analyzed, examined and placed in their appropriate context, one can judge the impact of student learning based on the discovery approach as a whole.

Appendix B: Discovery Based ISD

Modern technology provides ample opportunities for the scholars who may want to experiment with the discovery approach. Technology should not be viewed just as a growing trend; rather it must be intelligently implemented as a valuable instructional tool that can accommodate diverse learning styles of 21st century students (Watkins, 2005). The degree of processing speed, accuracy and retention that an individual is able to accomplish when encountering information depends upon to what extent the medium in which information presented matches his or her learning style (Barbe & Milone 1980 and 1981). It is important to acknowledge that students learn better when alternative modes of information processing are made available at college campuses (Grasha, 1996). One can recognize that the learning style of an individual student only by observing his/her overt behavior (Keefe 1988).

One may recall that instructional systems design, abbreviated, ISD was made popular by Walter Dick and Lou Carey whose famous quote is: *"You can't provide a solution until you know what the problem is."* The system that Dick and Carey proposed was ADDIE. The term ADDIE is an acronym for *Analysis, Design, Development, Implementation, and Evaluation.* In ADDIE, the completion of one step is logically fed into the one immediately after it (Dick & Carey, 1996). Dick & Carey's ADDIE system has been outlined and explained in Appendix I.

Instructors will be able to generate innovative ideas that can lead to effective classroom instructional strategies that can promote a vibrant interaction between the instructor and the learner. President of edCetra Training Company, Reuben Tozman says: *Instructional systems design is the reference used to describe a systematic approach to the design of instruction. A systematic approach implies a logical application of discovery, testing, and creating solutions.* ISD also refers to the methodical application of a process each and every time the creation of instruction is required (Tozman, 2004).

In a discovery approach, knowledge-based mastery of necessary functional skills needs to be stressed. Harvard University Professor Howard Gardner promotes what is known as *education for understanding.* Further, one should make sure that the assessment and evaluation is completely holistic (Gardner, 1993). This ensures that student success outcomes are exactly determined and is measured accurately (Armstrong, 1994). Many scholars have also recommended and supported a value-added concept of education by doing assessments before, during, *and* after a course (Barr & Tagg, 1995). In his book *Learning Paradigm College* John Tagg identifies essential features for generating such a paradigm and provides a flexible guide and a blueprint for implementing specific changes (Tagg 2003).

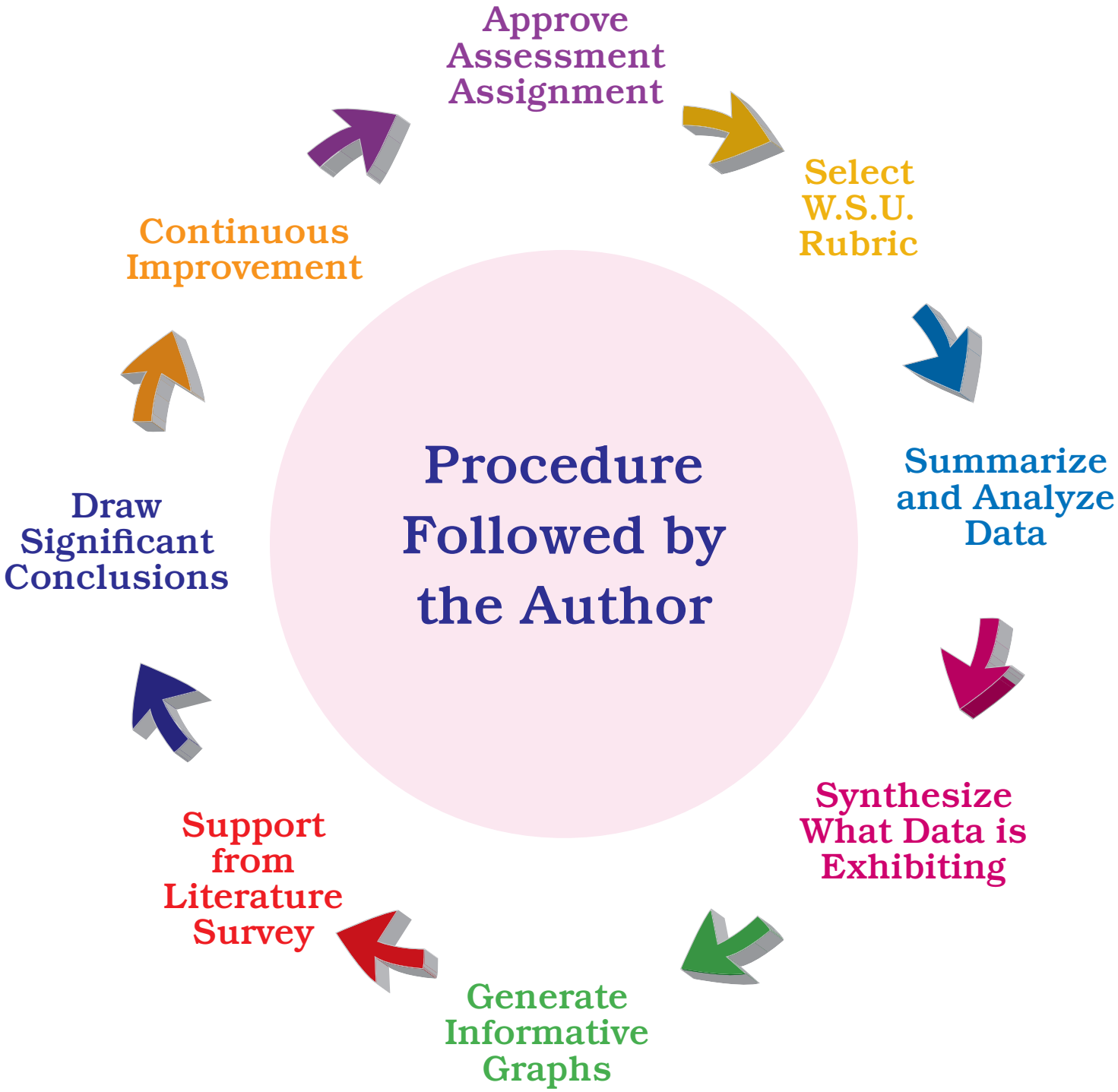
It is important that the aims and objectives of discovery approach are reflected in every aspect of the learning environment created. The creative new approach should document accomplishments at the upper levels of Bloom's Taxonomy Triangle (Bloom, 1956 & 1976; Boud & Feletti, 1991). Scholars in the area of cognitive science and educational psychology have identified four features that clearly separate a problem-based curriculum from a traditional, topic-based curriculum (Nickerson, et. al. 1985).

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

LIKERT SCALE ANALYSIS. 5: Strongly Agree 1: Strongly Disagree

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 non existent. 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
The author has utilized this rubric in several of his ASEE publications (2000 – 2012).


Approve Assessment Assignment
Select W.S.U. Rubric
Summarize and Analyze Data
Synthesize What Data is Exhibiting
Generate Informative Graphs
Support from Literature Survey
Draw Significant Conclusions
Continuous Improvement
Procedure Followed by the Author

APPENDIX E: Principles of Likert Scale

Likert scale is a type of psychometric response scale and is perhaps the most widely used instrument in sociology research. Likert scale is often used in research questionnaires and surveys. Presented with a statement, Likert scale attempts to measure and record either the positive or the negative response provided. Likert scale is a type of psychometric response scale. Rensis Likert, the American educator and organizational psychologist was the founder of *University of Michigan's Institute for Social Research.* Likert is best known for his research on management styles, development of Likert Scales and the Linking pin model (Likert, 1932). Just like W. Edwards Deming, Likert's books on theory of management were very popular in postwar Japan during the sixties and seventies.

While addressing and responding to a statement presented on a Likert scale questionnaire, respondents indicate whether they:

Strongly Agree (**5**); Agree (**4**); Undecided (**3**); Disagree (**2**); Strongly Disagree (**1**).

Numbers (**1** to **5**) are assigned to the responses received, however these numbers do not indicate the magnitude of difference between the responses. It is important to emphasize the fact that scores for these responses, **5 – 4 – 3 – 2 – 1** represent what is known as *ordinal level of measurement.* One may recall that in case of *ratio scale* or *interval scale* the magnitude of difference, indeed has a specific meaning attached to it. The data is not continuous. Therefore it must be interpreted carefully. It is not appropriate to generate or create a histogram using the data collected. Average values do not have any meaning for interpretation. Furthermore standard deviation does not convey anything. Therefore, the data are normally summarized using a median or mode. The author prefers to use *mode.*

The Likert Scale represents a built-in, inherent order or sequence. For example: Strongly Agree to Strongly Disagree; Biggest to Smallest; Strongest to Weakest; Tallest to Shortest; Largest to Smallest; Heaviest to Lightest; Maximum to Minimum;

References

1. Likert Rensis (2004). *Evaluation Cookbook,* Learning Technology Dissemination Initiative, Heriot – Watt University, Riccarton, Edinburgh, EH14 4AS, Scotland.
2. Likert, R. (1932). *A Technique for the Measurement of Attitudes.* Archives of Psychology 140, 55.
3. www.icbl.hw.ac.uk/ltdi/**cookbook**/info_**likert_scale**/printable.pdf

Appendix F: A Sample Excel Table (One Student's HW)

STUDENT # X

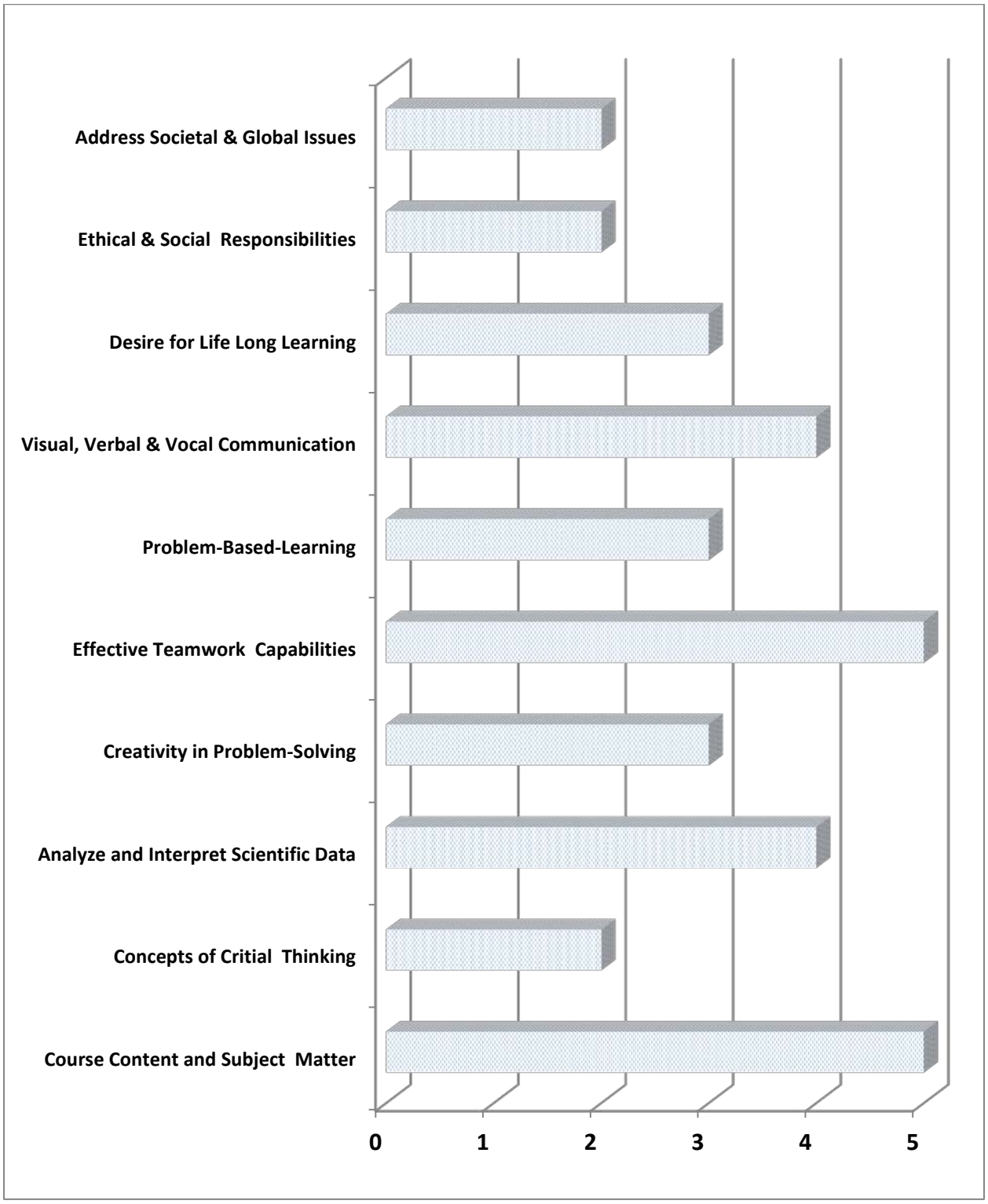
DISCOVERY APPROACH RUBRIC
COURTESY OF W. S. U.
WASHINGTON STATE UNIVERSITY
PULLMAN, WA. 99164.
LIKERT SCALE WEIGHT :

		STRONGLY AGREE 5	AGREE 4	UNDECIDED 3	DISAGREE 2	STRONGLY DISAGREE 1
1	Course Content and Subject Matter		√			
2	Concepts of Critical Thinking	√				
3	Analyze and Interpret Scientific Data		√			
4	Creativity in Problem-Solving			√		
5	Effective Teamwork Capabilities			√		
6	Problem-Based-Learning.	√				
7	Visual, Verbal & Vocal Communication			√		
8	Desire for Life Long Learning		√			
9	Ethical & Social Responsibilities	√				
10	Address Societal & Global Issues		√			

Appendix G: Consolidated Spreadsheet

Assessment of Discovery Appraoch																	
TOTAL 26 STUDENTS #	A	B	C	D	E	F	G	H	I	.	.	.	M	X	Y	Z	MODE
DISCOVERY APPROACH RUBRIC																	
RUBRIC COURTESY OF W. S. U.																	
WASHINGTON STATE UNIVERSITY																	
PULLMAN, WA. 99164.																	
LIKERT SCALE WEIGHT DISTRIBUTION :																	
(1 : Strongly Disagree; 5 : Strongly Agree)																	
Course Content and Subject Matter	4	4	5	5	4	4	4	4	5	.	.	.	4	4	4	4	5
Concepts of Critical Thinking	2	2	5	3	3	2	3	2	2	.	.	.	2	2	3	2	2
Analyze and Interpret Scientific Data	3	4	5	5	3	4	4	5	4	.	.	.	3	3	3	4	4
Creativity in Problem-Solving	3	3	5	5	4	5	5	4	3	.	.	.	5	3	5	3	3
Effective Teamwork Capabilities	4	4	5	5	4	4	4	5	4	.	.	.	4	4	4	4	5
Problem-Based-Learning	4	4	5	5	4	4	4	5	4	.	.	.	4	4	4	4	3
Visual, Verbal & Vocal Communication	4	3	3	3	4	4	4	3	3	.	.	.	4	3	4	3	4
Desire for Life Long Learning	3	3	5	5	4	5	5	4	3	.	.	.	5	3	5	3	3
Ethical & Social Responsibilities	4	4	5	5	4	4	4	5	4	.	.	.	4	4	4	4	2
Address Societal & Global Issues	4	3	3	3	4	4	4	3	3	.	.	.	4	3	4	3	2

Appendix H: Assessment Bar Chart



Appendix I: The ADDIE Model of Dick & Carey

Instructional Systems Design (ISD) was made popular by Walter Dick and Lou Carey whose famous quote is: *"You can't provide a solution until you know what the problem is."* Modern technology provides ample opportunities for the instructors to experiment on innovative ideas that can lead to effective classroom instructional strategies (Dick & Carey, 1996). Probably the most widely used *ISD* model is the *ADDIE* model proposed by Walter Dick and Lou Carey.

The term *ADDIE* is an acronym for
Analysis,
Design,
Development,
Implementation, and
Evaluation.

Here, in the *ADDIE* system, the instructor first starts with a *front-end analysis* of the instructional needs and sets the goals to be attained. Such an analysis tells the instructor about the characteristics of the learner. The learner is expected to bring in some prior knowledge, skill and experience to the course. This is supposed to provide some clarification to the instructor as to what level the *achievement-bar* can be set at. For example, the student may enter a *dynamics* course with a sound knowledge of college level *physics.* This tells the instructor that there is no need for a repeat discussion of *Newton's Laws of Motion.* The student already possesses adequate background knowledge that is necessary for a first course in dynamics. This is known as the ***Analysis*** stage.

The *Analysis* stage is then followed by the *Design* stage. Here the instructor determines the details pertaining to material content to be taught and generates an activity plan. One may also write specific course objectives based on learner's prior knowledge. The instructor can also outline how new information can be effectively presented to the learners, thereby developing a successful instructional strategy. The ***Design*** stage is very important because it involves careful planning that can result in optimum use of classroom time.

The ***Development*** stage follows the *Analysis* stage. Here the instructor selects the appropriate audio-visual techniques and integrates them to accomplish *knowledge-transfer.* One may use traditional lectures, reading assignments, writing projects, laboratory experimentation, group discussions, demonstrations, plant tours, design projects, art displays, sculpture studio presentations, stage performance, etc. Here one may be encouraged produce new material, to keep up with the *state-of-the-art.* One may generate and evaluate *sample* material. In industry, this is known as *Rapid Prototyping.*

The ***Implementation*** stage follows the *development* stage and this is where the instructor finally delivers the material to the learner according to the methodology outlined above. Here the instructor needs to collect adequate data to document that what was *designed* has actually been *delivered.* Feedback data must also be collected here so that the instructor can plan on further improvements.

The final stage is the ***Evaluation*** stage. All the assessment data gathered should be evaluated according to the rules set by the scientific disciplines. The instructor has the opportunity to review data collected and examine the importance of learner's comments. Based on the feedback the instructor may revise certain material content or delivery methodology. Some authors identify this stage with *seven R's.* Record, Recollect Report, Review, Retain, Reject and Revise.

There is also another model called *ASSURE* model, developed by Heinich, Molenda, Russell and Smaldino. *ASSURE* is an acronym for:

Analyze learner characteristics.
State objectives and goals.
Select, modify and design materials.
Utilize available material in the best possible manner.
Require and record response of the learners.
Evaluate the data collected for further improvement.

References:

Albanese, M. A., & Mitchell, S. (1993). *Problem-based learning: A review of literature on its outcomes and implementation issues.* Academic Medicine, 68 (1), 52-81.

Allen, D. E., Duch, B. J., & Groh, S. E. (1996). *"The power of problem-based learning in teaching introductory science courses."* In L. Wilkerson & W. H. Gijselaers (Eds.), *Bringing problem-based learning to higher education: Theory and practice* (pp. 43-52). San Francisco: Jossey-Bass.

Arámbula-Greenfield, T. (1996). *Implementing problem- based learning in a college science class: Testing problem-solving methodology as a viable alternative to traditional science-teaching techniques.* Journal of College Science Teaching, 26 (1), 26-30.

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

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

Barrows, H. S. (1996). *"Problem-based learning in medicine and beyond: A brief overview."* In L.Wilkerson & W. H. Gijselaers (Eds.), *Bringing problem-based learning to higher education: Theory and practice* (pp. 3-12). San Francisco: Jossey-Bass.

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

Barr, R. B., & Tagg, John (1995, November/December). *From teaching to learning: A new paradigm for undergraduate education.* Change, 13-24.

Baxter Magolda, M. B., & King, P. M. (Eds.). (2004). *Learning partnerships: Theory & models of practice to educate for self-authorship.* Sterling, VA: Stylus Publishing.

Baxter Magolda, M. B. (2001). *Making their own way: Narratives for transforming higher education to promote self-development.* Sterling, VA: Stylus Publishing.

Bloom, B. (1956). *A taxonomy of educational objectives. Handbook I: Cognitive domain*. New York: McKay.

Bloom, B. (1976). *Human characteristics and student learning*. New York: McGraw Hill.

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

Boyer, Ernest (1990). *Scholarship reconsidered: Priorities of the professoriate.* Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching.

Boylan, H. R. (2002). *What Works: Research-Based Best Practices in Developmental Education*. Boone, NC: National Center for Developmental Education.

Cambridge, Barbara (1999). *The scholarship of teaching and learning: Questions and answers from the field.* AAHE Bulletin, 3, 7-10.

Cerbin, William (1993). *Fostering a culture of teaching as scholarship.* The Teaching Professor, 7(3), 1-2.

Cerbin, William (1996). *Inventing a new genre: The course portfolio at the University of Wisconsin-LaCrosse.* In P. Hutchings, Making Teaching Community Property (pp. 52-60). Washington, D. C.: American Association of Higher Education.

Cross, K. Patricia & Steadman, M. H. (1996). *Classroom research: Implementing the scholarship of teaching.* San Francisco: Jossey-Bass.

Cutler, W. W. (1997). *The history course portfolio.* Perspectives. 35(8), 17-20.

Dantonio, M. (1990). *How can we create thinkers? Questioning strategies that work for teachers.* Bloomington, Indiana: National Educational Service.
Dick, W. & Cary, L. (1996). *The systematic design of instruction*. New York: HarperCollins Publishers.

Edgerton, R, Hutchings, P, Quinlan, K. (1991). *The teaching portfolio: Capturing the scholarship in teaching.* Washington, D. C.: American Association for Higher Education.

Engel, C E (1991). *Not Just a Method But a Way of Learning,* in Boud D and Feletti, G (eds) *The Challenge of Problem Based Learning.* London: Kogan Page.

Forrest, Aubrey (1990). Time will tell: *Portfolio-assisted assessment of general education.* Washington, DC: AAHE Assessment Forum. American Association for Higher Education.

Gardner, Howard (1993). *Frames of mind: The Theory of Multiple Intelligences (10th anniversary edition).* New York: Basic Books.

Grasha, A.F. (1996). *Teaching with style.* Pittsburgh, PA: Alliance Publishers.

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

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

Keefe, J. W. (1987*). Theory and practice.* Reston, VA: National Association of Secondary School Principals.

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

Linn, R., Baker, E., & Dunbar, S. (1991). *Complex, Performance-based Assessment: Expectations and Validation Criteria.* Educational Researcher, 20 (8), 15-21.

Narayanan, Mysore (2007). *Assessment of Perceptual Modality Styles.* Proceedings of 114th ASEE National Conference, June 24-27, Hilton Hawaiian Village, Honolulu, Hawaii.

Narayanan, Mysore (2008). *Assessment of Water Conservation Education.* Proceedings of World Environmental and Water Resources Congress 2008, May 12- 16, 2008. Honolulu, Hawaii. (ASCE.)

Narayanan, Mysore. (2010*). Assessment of Problem-Based Learning.* ASEE 117th Annual Conference and Exposition, Louisville, KY. June 20–23, 2010. Paper # AC 2010-15.

Nickerson, R.S., Perkins, D.N., Smith, E.E. (1985). *The Teaching of Thinking.* Lawrence Erlbaum Associates, Hillsdale, NJ, London.

Pascarella, E. T. & Terenzini, P. T. (1991). *How college affects students: Findings and insights from 20 years of research.* San Francisco: Jossey-Bass.

Paul, Richard (1995). *Critical Thinking: How to Prepare Students for a Rapidly Changing World.* Tomales, CA: Foundation for Critical Thinking .

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

Ryan, K. & Cooper, J. (2004). *Those Who Can, Teach (10 ed).* Boston, MA: Houghton Mifflin Company.

Saxe, S. (1990, June). *Peer influence and learning.* Training and Development Journal, 42 (6), 50-53.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization.* New York: Doubleday.

Sims, R. R. (1992, Fall). *Developing the learning climate in public sector training programs.* Public Personnel Management, 21 (3), 335-346.

Scriven, Michael (2002). *An overview of evaluation theories.* Evaluation Journal of Australasia, 1(1), 61-69.

Scriven, Michael & Paul, Richard (2010) http://www.criticalthinking.org/

Shulman, L. S. (1993). *Teaching as community property: Putting an end to pedagogical solitude.* Change 25(6), 6-7.

Seldin, Peter (1991). *The teaching portfolio.* Bolton, MA: Anker.

Tagg, John (2003). *The Learning Paradigm College.* Bolton, MA: Anker.

Walker, S. (2003). *Active learning strategies to promote critical thinking.* Journal of Athletic Training, 38(3), 263-267.

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

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

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

Young, C. O., Sr., & Young, L. H. (1999). *Assessing Learning in Interactive Courses.* Journal on Excellence in College Teaching, 10 (1), 63-76.