AC 2012-5561: ASSESSMENT OF DISCOVERY APPROACH

Dr. Mysore Narayanan, Miami University

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 Discovery Approach

Abstract

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, the instructor must encourage the establishment of a dynamic dialog that requires a deeper level of processing. We all agree on the fact that almost all professors ask the students to take ownership of their own learning. The discovery approach used by the author tries to build on these principles to 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. Educators 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. The author was inspired by the unique ideas presented by these scholars and researchers. He has tried to build on such intelligent ideas to develop a discovery approach of instructional technique. Discovery approach aims to help the students to accomplish more and achieve independence instead of interdependence. 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. In this presentation, the author describes how he has incorporated the principles of Socratic inquisition to assist the adaptation of the discovery approach. He also presents analyses of the feedback data he has collected and provides guidelines for continuous improvement.

Introduction

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). 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).

Provost David L. Potter of George Mason University recently chaired a joint task force and presented an exhaustive report entitled *"Powerful Partnerships : A Shared Responsibility for Learning."* One of the main goals of this report was to make a difference in the *quality* of student learning. Furthermore, it is important that the instructor assesses this difference and documents it for the implementation of continuous quality improvement (Potter, 1998). Aubrey Forrest of Emporia State University says that student portfolios, which document

learning in more detail, seldom reveal how teaching has effectively contributed to students' progress (Forrest, 1990).

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 was also a Whitehead Fellow at Harvard University and the recipient of the American Evaluation Association's Lazarsfeld Medal for contributions to evaluation theory. 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).

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 incorporated several ideas from this outline while he experimented with the discovery approach. Richard Paul's Taxonomy of Socratic Questions is very well known and is reproduced in Appendix J (Paul, 1995).

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. 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). One can also identify the importance of providing appropriate guidance and relevant training to the instructor as well as the student learner. These ideas lead us to the design and development of innovative instructional techniques as described below.

The Five Principles

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). Typically, the process of designing and developing classroom course curriculum content – not to mention, modifying content – could be effectively streamlined in a productive electronic environment. This has enabled the educators to examine the reusability of products. Furthermore, rapid development tools have facilitated the learners to admire and appreciate state-of-the-art technological innovations (Boyer, 1990). Discovery approach can be successfully implemented if an instructor intelligently incorporates and follows the five principles outlined below (Narayanan, 2010).

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 (Fleming and Mills, 1992). 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 (Narayanan, 2007 & 2008).

Discovery Approach Methodology

Discovery approach encourages the students to learn the facts, develop the skills and acquire the knowledge by *actively* working with the information gathered. The instructor encourages the learners to generate modules that demonstrate students' creativity. Most of the learners are indeed thrilled at this methodology because the students are no longer *passively* receiving information (Linn, Baker & Dunbar, 1991). Instructors, who establish a dynamic learning environment in the classroom, provide the students with an opportunity to take ownership over their own learning. Students will have the ability to make strong connections between concepts and concrete ideas with positive teacher-student and student-student interaction. Researchers have acknowledged the fact that problem based learning is an effective method that can improve students' critical thinking capabilities. However, it must also be recognized that these active learning methodologies do necessarily require additional work on the part of students as well as faculty (Barrows, 2000). A pioneer in the area of problem-based learning, McMaster University Professor Emeritus, Dr. Donald R. Woods describes a curriculum that is significantly different from the traditional discipline centered curriculum (Woods, 1994).

Discovery approach aims to march a step further, when compared with problem-based learning. Here the instructor may benefit from the ideas provided by *Intel Education.*

(http://www.intel.com/education/designprojects/)

1. Authentic project work puts students in the driver's seat of their own learning.

2. Instructors should take advantage of curriculum developed by teachers in a large collection of Unit Plans that integrate technology.

3. Models of meaningful classroom projects that integrate instruction in developing critical thinking skills provide the learners with an opportunity to enhance their knowledge.

4. Tools and strategies for developing one's own exemplary technology-supported learning should always receive encouragement from the instructor

5. It is important to learn how project-based units can effectively engage students in meaningful work and promote higher-order thinking.

6. It is necessary to see how questions and ongoing assessment keep project work focused on important learning goals.

7. One needs to gather ideas from a collection of exemplary Unit Plans and design one's own technology-rich teaching plan.

One can conclude that learning has taken place when the instructor observes a change of learner behavior (Keefe, 1988 & 1991)). 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 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 1987).

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).

Assessment Procedure

Assessment of the Discovery approach was carried out by the author using several proven, well established and widely recognized tools (Rowntree, 1977).

Sample quizzes, homework assignments, examinations, written reports were graded on a holistic basis using likert scale principles. These were recorded in a tabular form using an excel spreadsheet. A matrix was generated to document grading and analysis. A sample excel table for grading one student's single homework assignment quiz is shown in Appendix E.

It is necessary to generate separate matrix tables for *each* 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 easily streamline the task on hand.

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

The important aspect here is to move away from a teaching paradigm to learning paradigm that is based on the discovery approach.

The principles assessment methodology can be summarized as follows.

1. The participants should be capable of generating or selecting an assessment plan, that is productive and that is best suited for their chosen discipline.

2. The participants should make a choice of developing a set of rubrics that can be effectively utilized in administering their assessment procedures.

3. The participants are required to finally generate a set of graphs that can provide them with appropriate feedback pertaining to student learning capabilities.

It is quite common for colleges and universities to offer several types of precollege-level courses. These types of courses are basically designed to teach the essential academic skills that are necessary for success in some chosen upper level courses (Brier, 1984). For example, a pre-calculus course may be necessary for a group of students who may be quite competent in English literature. Another example would be a technical writing course that could help scientists, mathematicians and engineers with their journal publications.

Implementation

For the implementation of the discovery approach, the author tried to address eight important questions while he tried to design a new course curriculum content. The author has previously used a similar approach in other research projects to obtain meaningful results.

1. What should be counted as appropriate goals and accomplishments in an undergraduate engineering course that has a significant laboratory component?

2. Does the discovery approach practices utilized by the instructor providing reasonably acceptable paths toward accomplishing the specified learning goals in the chosen course?

3. What do students actually accomplish in the designed course and the laboratory exercises? How has discovery approach helped them in meeting their learning goals?

4. How has the instructor’s organizational techniques contributed towards students' intellectual development and progress?

5. Has the discovery approach methodology effectively responded to address students' learning difficulties?

6. Does the teacher revise his discovery approach methodology to address such problems encountered by the students?

7. What impact does this type of discovery approach have on students' life-long learning attitudes?

8. Does the discovery approach help the students to develop the ability to *"learn, how to learn."*

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

2. 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 B.

3. 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 C.

4. Anthony F. Gregorc is best known for his theory of a *Mind Styles Model* and *Gregorc Style Delineator.* Discovery approach was strongly influenced by Gregorc's *Mind Styles Model.* Dr. Gregorc's powerful and widely used instrument is shown in Appendix D.

5. The data collected has been tabulated using an excel spreadsheet. A sample excel table for one student's quiz has been reproduced in Appendix E.

6. A consolidated master spreadsheet excel table that was generated using data collected from various students has been reproduced in Appendix F.

7. A bar graph was generated to facilitate analysis and this is shown in Appendix G.

8. Summary of some of the selected characteristics of discovery approach and discussion of the bar graph and results has been recorded in Appendix H.

9. Richard Paul's Taxonomy of Socratic Questions system has been outlined and explained in Appendix I.

Analysis

Generation of a well designed bar chart provides the instructor proper guidance with visual data analysis. Important strengths and weaknesses can be easily identified using the bar chart. 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.

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

Discovery Approach Delivers Content:

This was the first and foremost criteria. The author wanted to make sure that appropriate material was covered at the necessary depth as well as the required breadth. The subject matter studied was *engineering mechanics: statics.* It was essential that the students acquired a very strong foundation of the fundamental principles. Statics is used as a very important foundation course for a variety of subsequent topics such as strength of materials, dynamics, fluid mechanics, machine elements, machine design, manufacturing processes, etc. It is observed that this category recorded the maximum possible score of **5** on the Likert scale. This indicates that the instructor did *cover the material.* The author is extremely pleased with this result. It must be reiterated that no new instructional technique should be introduced while sacrificing needed course content.

Discovery Approach Reinforces Knowledge:

This criterion closely follows the first criteria. Scholars in the area of cognitive science and educational methodology stress the importance of a strong foundation more commonly identified as *declarative learning.* Building up on student's strengths ultimately leads to successful learner accomplishments in subsequent tasks. A respectable Likert scale score of **4** has been recorded for this characteristic. The author is fairly satisfied with this result. However, he has decided to gather more feedback from students as to how this can be improved. The author wants that this category should also achieve the maximum possible score of **5** on the Likert scale.

Discovery Approach Promotes Integration:

This category has recorded an average Likert scale score of **3** which is not acceptable from the authors point of view. Professional and technical students must learn to integrate the laws of physics and rules mathematics in to their engineering design methodologies. Evidently the instructor has not provided enough tools to accomplish this. The author assumes and accepts responsibility for not having implemented certain strategies that could have forced the learners to appreciate the importance of integrating previously acquired knowledge. The author has decided to design and develop more reading assignments and homework problems that focuses on this issue. The author wants to improve this score to at least **4** initially.

Discovery Approach Develops Communication Skills:

Engineers need to proficient not only in technical knowledge, but also be proficient in communication skills. This encompasses all the three, namely verbal, visual and vocal. The author designed ten writing assignments with the help of Miami university's writing center. These were aimed at developing students' written communication skills. The author required the students to generate and present a power point presentation on the subject matter of bridge design. The objective was to develop and reinforce students' visual and vocal communication skills. It is observed that this category also has recorded a respectable score of **4** on the Likert scale. The author was fairly pleased with students' performance in the area of *communication skills.* The author is examining certain new ideas that could perhaps improve this score to the maximum possible level of **5** on the Likert scale.

Discovery Approach Creates Challenges for the Learners:

Effective educators want to challenge the learners at their appropriate skill level. Here, the objective is to ensure that the students are not *bored* with some routine *plug-and-chug* problems. At the same time, the task presented to the student must not exceed learner's competency levels. Students will soon be frustrated if one tries to demand far in excess of what is really required and reasonable. This category has recorded a low Likert scale score of **2** which is considered totally unacceptable. This shows that the students do indeed have great potential to tackle much more complex problems that involve sophisticated engineering methodologies and mathematical techniques. The author has not created an environment wherein the students have been challenged enough. This leads the author to arrive at one possible conclusion. Raise the bar higher. The author must strive hard to improve this score initially to at least **3** initially, later to **4** and ultimately to **5.**

Discovery Approach Helps Diverse Learners:

Researchers have indicated that problems related to learning most frequently are not related to the complexity of the subject matter. 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 the student's learning style. Educators must be able to successfully address the needs of the individual by relating their own teaching style to the learning style of the individual student. The author wanted to focus on a well established fact that student learning is actually an interactive process that takes place in an educational environment established specifically to promote and enhance knowledge in a discovery atmosphere. This category also has recorded an unacceptable Likert scale score of **2** which indicates that the author's approach is not working. The author has decided to obtain some productive feedback from *The Learning Center* at Miami University, which is equipped to provide academic support services for a variety of student needs.

Discovery Approach Supports Critical Thinking:

Michael Scriven & Richard Paul have defined Critical thinking as the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or

evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action (Scriven & Paul, 2010). This category has recorded an average Likert scale score of **3** and the author considers this to be unacceptable. Engineers need to become very good critical thinkers. Industry needs professionals who are capable of examining a problem critically to arrive at justifiable solutions. Engineers are faced with different scenarios every day and are required to draw significant conclusions based on their evaluations. A traditional strength of Miami University is that its heavy emphasis on liberal education. Miami University was founded on the belief that a liberal education provides the best possible framework for life in a changing world. The author will try to extract some creative ideas out of *Miami Plan for Liberal Education.* Hopefully this would help him to promote critical thinking in his future endeavors.

Conclusions and Continuous Improvement

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* (Narayanan, 2007).

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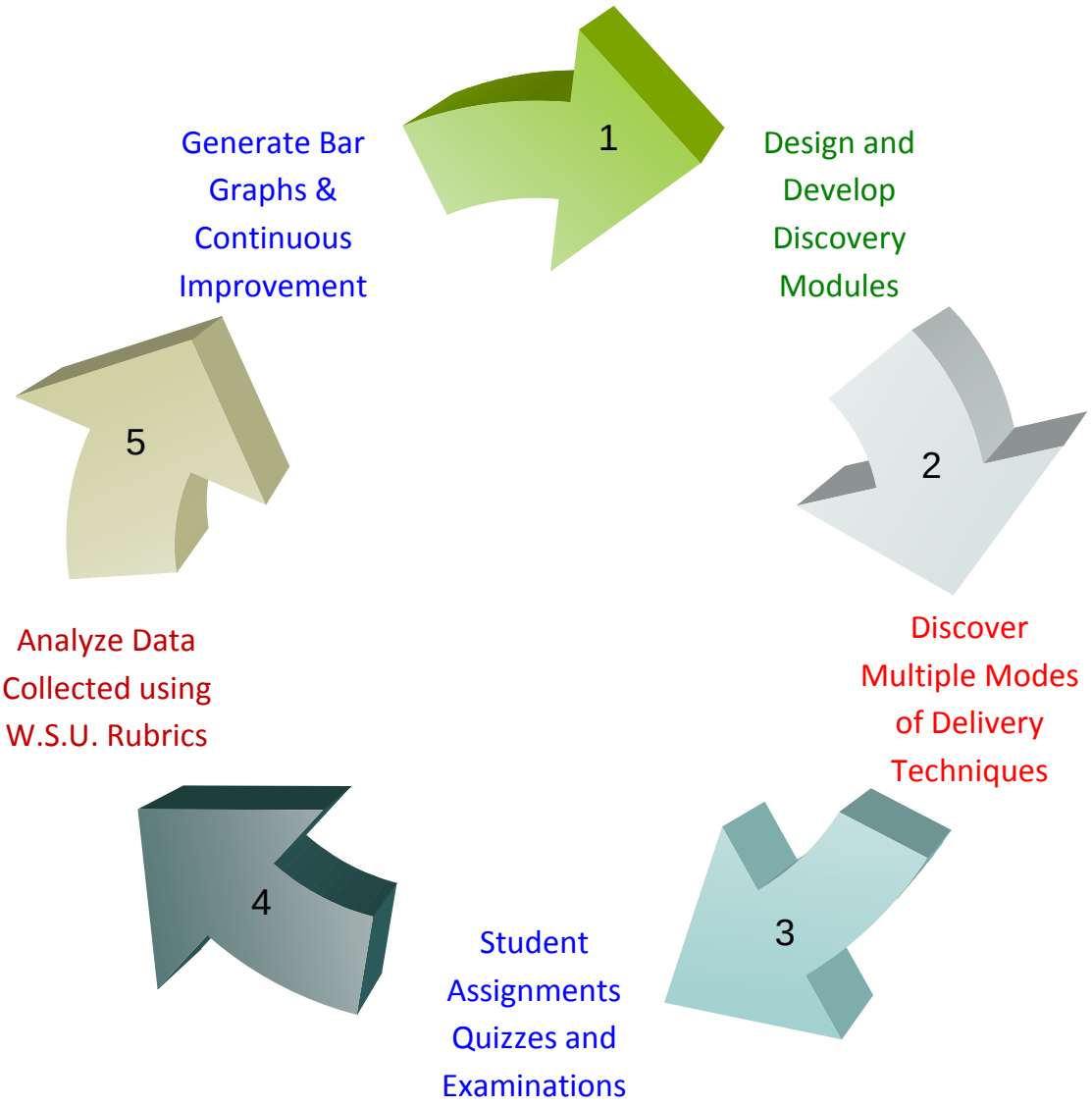
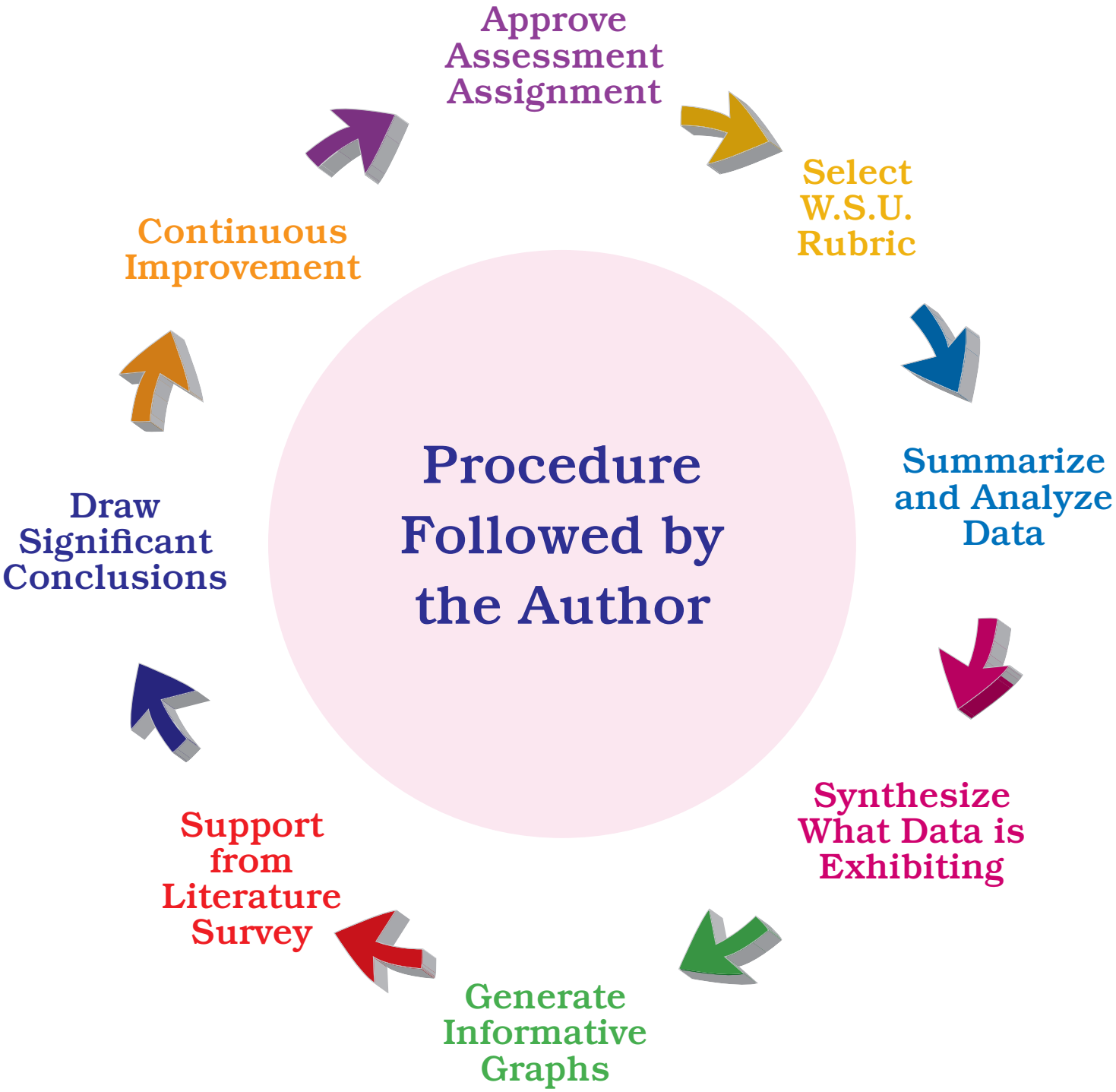
APPENDIX A: Methodology used by the author.



The author has previously used a similar approach in other research and other ASEE publications


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

	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 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

APPENDIX C: Principles of Likert 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.

A Likert scale is often used in research surveys and questionnaires.

Likert scale is a type of psychometric response scale.

Likert Scale is perhaps the most widely used instrument in sociology research.

Likert scaling is referred to as a bipolar scaling method.

Presented with a statement, Likert scale attempts to measure and record either the positive or the negative response provided.

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

Strongly Agree (**5**),

Agree (**4**),

Remain Undecided (**3**),

Disagree (**2**)

Strongly Disagree (**1**).

It is important to emphasize the fact that these responses, **5 – 4 – 3 – 2 – 1**

represent what is known as *ordinal level of measurement.*

This is much different from other scales such as *ratio scale* or *interval scale.*

The Likert Scale represents a built-in, inherent order or sequence. For example:

Strongly Agree to Strongly Disagree.

Biggest to Smallest.

Maximum to Least.

Strongest to Weakest.

Tallest to Shortest.

Heaviest to Lightest.

Largest to Smallest.

Etc.

Numbers (**1** to **5**) are assigned to the responses received, however these numbers do not indicate the magnitude of difference between the responses. 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. Mean (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.*

Source:

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 D: Gregoric Style Delineator: Four learning styles

Discovery approach was strongly influenced by Anthony Gregorc's *Mind Styles Model.*

Concrete Sequential (CS) These learners prefer direct, hands-on experience. They exhibit extraordinary development of their five senses. They like touchable, concrete materials, and orderly presentations. CS's actually enjoy faculty meetings! They are adverse to change and do not oppose tradition. They are habitual, punctual, and desire perfection. You would not see a CS wear flashy colors or mismatched outfits. They are organized, desire perfection, and give "practical" gifts.

Abstract Random (AR) These learners have a capacity to sense moods, and they use intuition to their advantage. They prefer to learn in an unstructured environment such as group discussions and activities. Faculty meetings are viewed as a time to socialize! They prefer not to be restricted by unnecessary rules and guidelines. Because AR's continuously discharge energy, they may appear "hyper" when indeed they are not. AR's use hand and body movements when communicating. They dislike routine activities and cold, unemotional people.

Abstract Sequential (AS) These learners have excellent abilities with written, verbal, and image symbols. They like to read, listen, and use their visual skills. They are highly verbal; therefore, you will never have a short conversation with an AS. They prefer a sequential presentation that is rational and substantive or they consider meetings a waste of time. AS's are "fence straddlers" and highly skeptical.

Concrete Random (CR) These learners like to experiment using trial-and-error approaches. They tend to jump to conclusions and prefer to work independently or in small groups. They are gamblers and risk takers. CR's may arrive late to meetings and leave early if they feel the meeting is boring or going nowhere. Concrete Random individuals are leaders, not followers. They love to take charge and be in charge. They refuse to accept the words "don't" or "can't." They thrive in a competitive atmosphere. CR's are not overly concerned with making impressions or going out of their way to win over people. They are often the prime movers of change.

Source:

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

2. Gregorc, A. F. (1979). *Learning styles: Differences which the profession must address.* Reading through content, 29-34.

3. Gregorc, A. F. (1979). *Learning/teaching styles: Their nature and effects.* Student learning styles: Diagnosing & prescribing programs, 19-26.

4. Gregorc, A. F. (1984). *Style as a symptom: A phenomenological perspective.* Theory into Practice, *23*(1), 51-55.

5. Gregorc, A. F., & Ward, H. B. (1977, February). *A new definition for individual.* NASSP Bulletin.

Appendix E. Matrix that was generated to document holistic grading and assessment analysis.

A sample matrix for one student's single homework assignment report is shown here.

Subject: ENGINEERING MECHANICS: Statics.

QUIZ # 6: Seven questions addressed the following requirements:

Question # 1. Pertained to the mathematical analysis of a simple truss. (Content)
Question # 2. Required the application of laws of physics. (Reinforces Knowledge)
Question # 3. One needed to utilize the knowledge of chemistry of metals. (Integration)
Question # 4. A written research report of 400 words was required. (Written Communication Skills)
Question # 5. This problem was *thought provoking* and required three dimensional analysis. (Challenging)
Question # 6. Students had a choice to use Mathematics, MATLAB or EXCEL. (Diverse Learners)
Question # 7. Failure of a structural component was to be critically evaluated. (Critical Thinking)

STUDENT # X

THE DISCOVERY APPROACH MATRIX
RUBRIC COURTESY OF W. S. U.
WASHINGTON STATE UNIVERSITY
PULLMAN, WA. 99164.
QUIZ # 6: STATICS

		5 STR. AGREE	4 AGREE	3 UNDECIDED	2 DISAGREE	1 S. DISAGREE
1	Discovery Delivers Content	√				
2	Discovery Reinforces Knowledge		√			
3	Discovery Promotes Integration			√		
4	Discovery Develops Communication		√			
5	Discovery Creates Challenges				√	
6	Discovery Helps Diverse Learners				√	
7	Discovery Supports Critical Thinking			√		

Appendix F:

Master Spreadsheet for Consolidating Data Collected from a Group of Students

GRADING:		
	QUIZZES:	20%
	HOMEWORK:	20%
	EXAM # 1:	20%
	EXAM # 2:	20%
	FINAL:	20%

Assessment of Discovery Approach

QUIZ # 6 ..... TOTAL xx STUDENTS #	A	B	C	.	.	.	.	X	Y	Z	MEDIAN	MODE	AVG.

THE DISCOVERY APPROACH MATRIX (CONSOLIDATED)
RUBRIC COURTESY OF W. S. U.
WASHINGTON STATE UNIVERSITY
PULLMAN, WA. 99164.
LIKERT SCALE WEIGHT DISTRIBUTION :
(1 : Strongly Disagree; 5 : Strongly Agree)

Discovery Delivers Content	4	4	3	.	.	.	.	4	3	3	5
Discovery Reinforces Knowledge	3	4	5	.	.	.	.	5	5	5	4
Discovery Promotes Integration	5	4	3	.	.	.	.	3	4	5	3
Discovery Develops Communication	3	3	5	.	.	.	.	4	3	4	4
Discovery Creates Challenges	3	3	5	.	.	.	.	5	4	4	2
Discovery Helps Diverse Learners	4	4	5	.	.	.	.	5	4	5	2
Discovery Supports Critical Thinkings	4	3	4	.	.	.	.	3	4	3	3

Data Collected & Consolidated by : Mysore Narayanan.

The data collected are ordinal: they have an inherent order or sequence, but one cannot assume that the respondent means that the difference between agreeing and strongly agreeing is the same as between agreeing and being undecided.
Descriptive Techniques (Likert Evaluation Cookbook 2004)
Summarize using a median or a mode (not a mean); the mode is probably the most suitable for easy interpretation.
Express variability in terms of the range or inter quartile range (not the standard deviation).
Display the distribution of observations in a dotplot or a barchart (it can't be a histogram, because the data is not continuous).

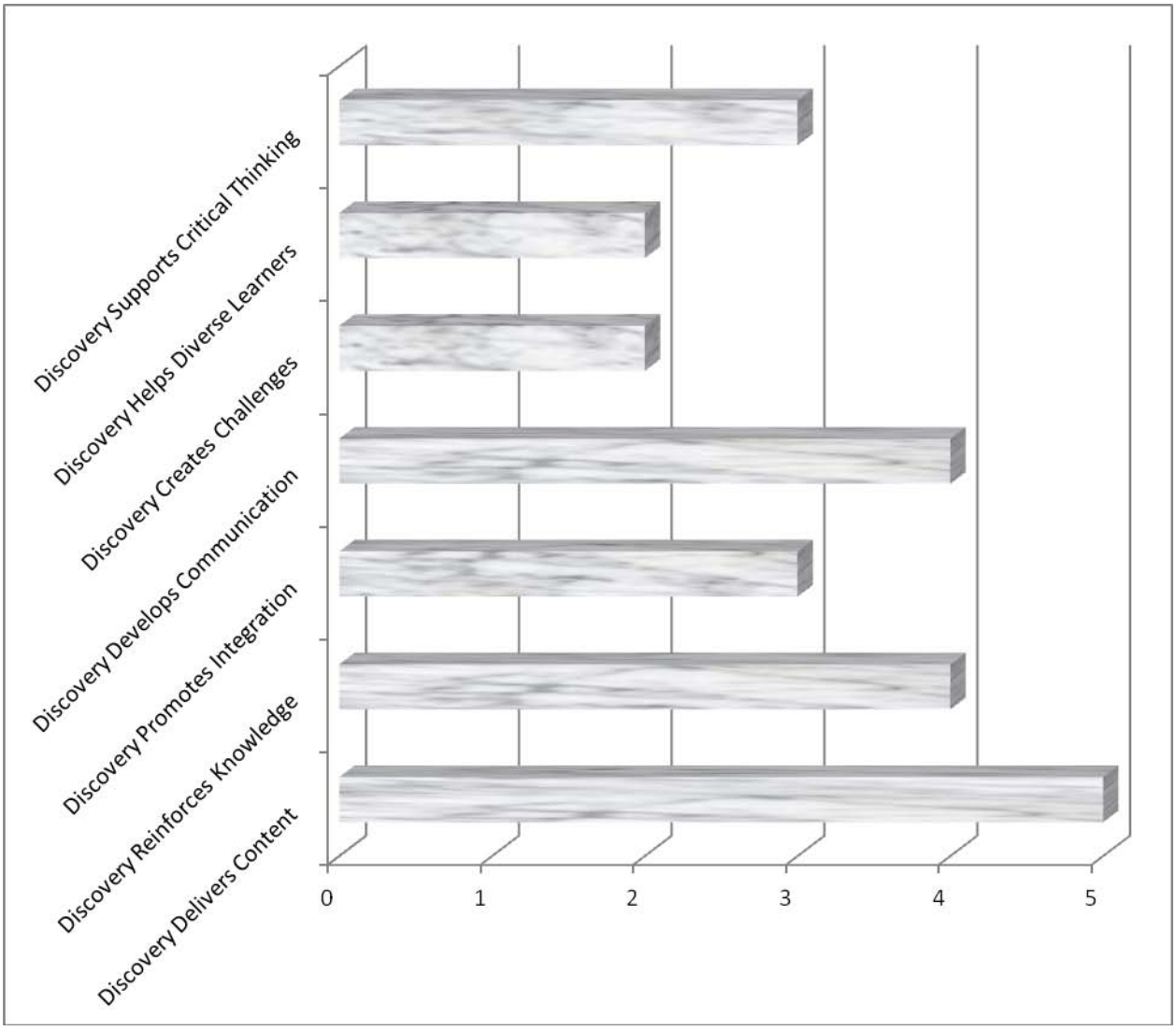
Appendix G:

Bar Chart Analysis of Seven Selected Characteristics of Discovery Approach

LIKERT SCALE ANALYSIS.

5: Strongly Agree.
4. Agree.
3. Undecided.
2. Disagree.
1: Strongly Disagree.

Please see pages 8 – 10 for a complete descriptive analysis of the bar chart data.



Appendix H: Some Selected Characteristics of Discovery Approach

Appendix I: Taxonomy of Socratic Questions

Richard Paul created a taxonomy of Socratic questions in support for problem based learning (PBL). The taxonomy is not a hierarchy in the traditional sense. The categories build upon each other, but they do not necessarily follow a pattern or design. One question's response will lead into another category of questioning not predetermined by the facilitator.

In keeping with the problem based learning (PBL) philosophy, this aspect of the model is most conducive! The role of the skilled facilitator is to keep the inquiry "train on track," but, also, to allow participants to "travel to a viable destination" of their own design. Paul suggests six types of questions that probe reasons and evidence:

1. Questions of Clarification
2. Questions that Probe Assumptions
3. Questions that Probe Reasons and Evidence
4. Questions about Viewpoints or Perspectives
5. Questions that Probe Implications and Consequences
6. Questions about the Question

A Socratic questioner should:

1. Keep the discussion focused.
2. Keep the discussion intellectually responsible.
3. Stimulate the discussion with probing questions
4. Periodically summarize what has been dealt with and what needs to be resolved.
5. Draw as many students as possible into the discussion.

Source : Paul, Richard, Critical Thinking: How to Prepare Students for a Rapidly Changing World, 1995.

REFOCUSSING QUESTIONS – Used when the student does not answer your initial question. Restate the student's response, and then restate your original question. For example: "You are telling me about the cause of depression". I asked you about the effects of depression. "What are some of the effects of depression?"

NARROWING THE FOCUS QUESTIONS – Used when the student is not responding to your question because they do not understand the question or the content required to answer the question. Reword or reduce the amount of information in the question. For example: Change the question: "What did you observe during the treatment session?" to "What can you tell me about the client's motion available for getting dressed?"

CLARIFYING QUESTIONS – Used when the student's answer is unclear, or if you would like to help them put the answer into different words. Do not give any further information, but ask the student to rephrase his/her response. For example: "What do you mean by the client appears frustrated?"

VERIFYING QUESTIONS – Used when you would like the students to provide further information to support their answer. This type of question helps establish the accuracy of the information and the level to which the student understands his/her response. For example: "What did you see that made you say that the client has problems with muscle weakness?"

SUPPORTING QUESTIONS – Used to bring the student's thinking out, and to help the instructor and student see how the student is connecting and explaining information. This type of question asks the student to state why or what the basis is for the answer that they gave. For example: "Why do you think that she is unsafe transferring into the tub?"

Source: Dantonio, M. (1990). *How can we create thinkers? Questioning strategies that work for teachers.* Bloomington, Indiana: National Educational Service.