Session #3650

"Research, Report Writing, and Representation": The Most Viable 3Rs for Critical Thinking and Effective Communication Skills in SMET Education.

By

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ABSTRACT

The use of research for the development of critical thinking and effective communication skills is a current trend in science, mathematics, engineering and technology (SMET) education. This trend is epitomized by the National Science Foundation (NSF) sponsored Research Experiences for Undergraduates (REU) program; currently there are approximately 300 REU sites nationwide. The role of research in critical thinking and communication skills development is optimized when used in combination with report writing and report presentation (representation). The 3Rs (Research, Report Writing, and Representation) incorporate the essential elements of critical thinking and effective communication such as literature search for development of ideas (ideation) and knowledge base, experimentation for verification of developed ideas and data generation, analyses and interpretation of generated data using course concepts and fundamentals, report writing for documentation of research results and development of writing skills, and report presentation for development of oral communication skills and dissemination of research findings.

1. Introduction

The use of research as a viable instructional and educational tool is a current trend in academia.

The concept of the 3Rs, research, report writing and representation (report presentation) is a very viable medium for critical thinking and effective communication skills especially when utilized as a total package, as is frequently the case. Invariably, accreditation agencies, funding agencies, educational organizations and even industry are requiring the dissemination of research findings vis-à-vis project reports, publications and presentations, as standard operating procedure. It is typical for faculty who engage in research to involve their students in one form of research or another[(1)]. This pedagogical approach to instruction and education popularly referred to at the Pittsburg State University (PSU) College of Technology as "by doing learn" is based on the concepts of mentoring, advisement and guidance. Research inherently involves planning, organization, direction, control, discipline, and most importantly ideation and implementation; these are some of the elements of critical thinking.

One of the foremost and current definitions of "critical thinking" is given by Joanne Gaine

Kurfiss: [2][3] "Critical thinking is a process of inquiry that involves the interplay of knowledge, skills, beliefs, attitudes and conditions directed toward forming understanding of a complex problem, question or issue. The outcome of this inquiry is a well-reasoned, well-supported argument, interpretation or other product that reflects a **disciplined** pursuit of the question." This definition encompasses such essential elements of critical thinking as:

- knowledge and understanding of the subject matter,
- goal setting and motivation,
- metacognition or the capacity to control and utilize mental processes in pursuant of set goals,
- syntheses, analyses and evaluation or development of intellectual skills,
- epistemology or role of the individual in the design, development and creation of knowledge,
- innovative application of acquired knowledge,
- ethical responsibility and accountability for developed or acquired knowledge.

These espoused elements of critical thinking; particularly metacognition and the innovative application of acquired knowledge are the "driving force" for industrial and societal productivity. "Productivity" as represented by the GDP (gross domestic product) and GNP (gross national product) has been cited as the leading criterion for civilization[4][5].

For the past several years, industry has been stressing the critical role of communication skills (effective communication, that is) in logistics and the productivity chain. Academia's response to industry's initiative has been very positive; SMET programs have bolstered and incorporated new elements of communication in their curricula. Communication in its simplest form involves the transfer or transmission of information, data or ideas from a generator (initiator) to a receptor. Effective communication on other hand is much more involved and requires extra steps or efforts to ensure that the transmitted information, data or ideas are user-friendly and receivable by the receptor. Figure I below represents a modified version of the Claude Shannon information theory model as depicted by Vardaman and Halterman[6]. Figure I shows the key elements of an effective communication system vis-à-vis: a common field of experience or convergent fields of experience of the communicators (A), initiation of communication that involves thinking out of the idea(s) or core purpose of communication (B), encoding and packaging of thought out idea(s) for meaningfulness, understanding and ease of delivery (C), the signal (D), decoding or analysis and interpretation of the signal (E), and reception, understanding and implementation of the idea(s) and goal(s) embodied in the message. Invariably, a communication system is as good as its weakest link. Hence, for meaningfulness, understanding and usage of information, the coding, signal and decoding elements must occur within a common field of experience or empathic psychological set of the communicators[7]. Commonness of field of experience also includes the element of feedback or post-signal reception communication between initiator and receptor to confirm adequacy, validity and conclusion of communication. In addition, commonness of field of experience emphasizes the interactiveness, team concept and goal-orientedness of effective communication.

The objectives of this paper are to

1. reiterate the pedagogical approach of the use of research as a viable instructional and educational medium for critical thinking skills,
2. advocate the use of the concept of the 3Rs as a total package for critical thinking and effective communication skills,
3. advocate the incorporation of the concept of the 3Rs in SMET courses and curricula, and
4. utilize the 3Rs' process as implemented in a plastic materials course to demonstrate the viability of the 3Rs' concept as medium for critical thinking and effective communication skills.

This paper will elucidate the seven essential elements of critical thinking afore stated as espoused by Kurfiss and Bloom and the associated effective communication skills with a discussion of the 3Rs' process.

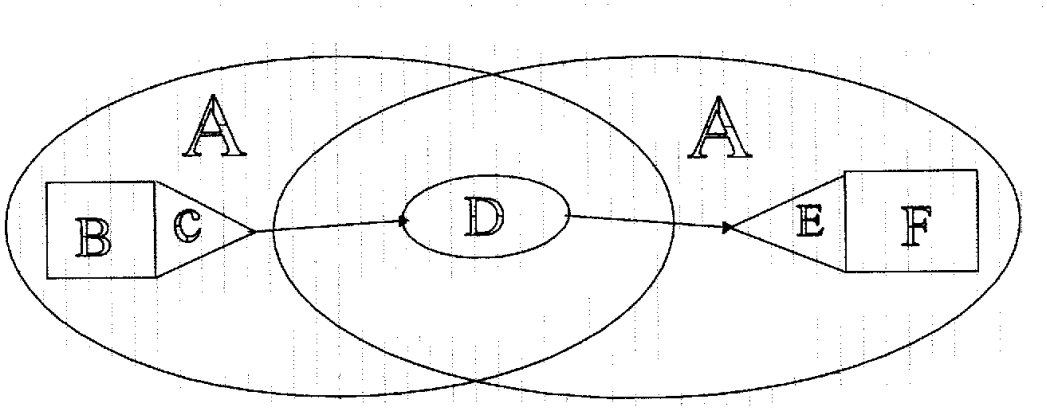

Figure I: Elements of an Effective Communication System[6]
A = Field of Experience; B = Source of Communication – Thinking out of Ideas;
C and E = Synchronized Coding System – Encoding and Decoding Respectively;
D = Signal – Transmitted and Received; F = Destination – Deciphering/Understanding/ Usage of Received and Decoded Information.

2. Research, Report Writing , and Representation (3Rs): The Process

As stated previously, implementation of the 3Rs is key to the development of critical thinking and effective communication skills; the 3Rs' process is paramount when incorporating research in a course. The time limit imposed by the typical semester duration implies the primary product of the course research is not a "urethane foam base ball bat" or "smart marble" or "a novel biodegradable material" or "a polyolefin-based fuel cell electrolyte matrix", or "an electrically-conductive plastic" or etc. but a well written paper documenting the research efforts. Actual products do result but these are secondary to the written report and report presentation combination. Also considering that a typical course has other activities such as assignments, quizzes, exams etc., the 3Rs component is assigned 10% of the course grade. (Other percentages are possible. When this author taught a sophomore level plastic materials and processes course at Purdue University during a nine-month sabbatical stint, the 3Rs' process was assigned a grade of 5% because report was based on a choice laboratory experiment). The report presentation

(representation) is worth the equivalent of two class assignments. Allotment of grade points to these activities is an incentive or motivation for the student. Students relate very well to the grade award system. Of course, it is necessary and important to specify/state the grade distribution format in the course syllabus, and to discuss this on the first day of class meeting. While this is a good start additional mentoring and guidance strategies on the part of the instructor are required through out the course to ensure full participation by the student and for a successful implementation of the 3Rs'process. This is so because this pedagogical approach to instruction and education may be new to the student, the typical sophomore and junior and even senior is accustomed to the traditional course requirements of assignments, quizzes and exams. Having decided that the report writing is the primary product of the 3Rs' process, the report-writing format must be specified. In the plastic materials courses at PSU, the three predominant forms of report utilized in the laboratory section are briefings, memo and formal reports[(8)(9)(10)]. The formal report format is the preferred report writing format since it contains most of the elements of a standard, technical report, and consists of: Letter of transmittal, title page, table of contents, summary (abstract), introduction, relevant literature, main body of paper under an appropriate heading, experimental section (equipment used, materials used, procedure), results (data table, data plots and physical description of data), discussion of results (accuracy, precision of data, analyses and interpretation of results), conclusions, recommendations, resources cited and appendix.

The experimental section requirement of the formal report makes the student's work original, unique and authentic; a well-planned and implemented simple laboratory experiment provides data that can be analyzed and interpreted. The formal report format also provides a framework for the initial planning and organization of the semester's research project. The first laboratory meeting of the course is used to explain the different forms and elements of report writing and the student is encouraged to use the instructor's office hours through out the semester for clarification on any course subject. Mentoring, guidance and advisement are all outcomes of use of the instructor's office hour. This inculcates in the student the use of consultation at the peer, supervisory, managerial and executive levels as a medium for effective communication. "Staff meeting" is a common and standard forum for discussion of relevant and important organizational and industry operational activities. Staff meetings provide dynamism and improved operation techniques as organization members exchange ideas based on experience and knowledge. Exchange of ideas produces awareness, and the employees have better levels of problem anticipation. Enhanced level of problem anticipation is the foundation for operational preparedness. Policy decisions made at these meetings ensure strong support for such by members of the organization, and management does not have to devote extra time and resources trying to sell these ideas.

Approximately one month into the semester, after the first examination, the research project is officially introduced by providing the class with a list of generic research topics and a timeline (Table I) for the 3Rs' process. Table I indicates the requirement for the student to submit a list of three specific research topics. The student is assigned one of the chosen topics. For the approximately two month duration of the research project the student as part of the mentoring advisement and guidance strategy, is required to use the instructor's office hours at least twice to facilitate the topic selection, report outline and project implementation process.

Table I: **TOPICS FOR TERM PAPER**

1. Innovations in Casting of Transparent Thermoplastics
2. Experimental Determination of Molecular Weight by Viscosity Methods
3. Cost-effective Recycling of Plastic Materials
4. Compatibility of thermoplastics In Blends
5. Conductive Plastics
6. Biodegradable Plastics
7. Plastics in Medical Applications
8. Thermoplastics in Composites
9. Metallocene-based Thermoplastics
10. Thermoplastics in Automotive Applications
11. Cross linking Thermoplastics and Their Applications
12. Liquid Crystalline Polymers (LCP's)
13 UV-Stabilization of Polypropylene
14. Thermoplastics in Toy Manufacturing
15. Thermoplastics in Energy Systems (Fuel Cells)

** Choose ***any three specific topics*** (including those not listed) that are of interest to you and list them in the order of preference. One of the topics will be assigned to you for your term paper.

*** You are encouraged to choose an ***experimentation-based*** topic for your term paper.

SCHEDULE FOR TERM PAPER

Friday, September *22*, 2000:	Distribution of Topics
Friday, **September 29**, 2000:	List of Three Topics Due
Wednesday, October 04, 2000:	Assignment of topics
September 04 – October 20, 2000:	**Use Instructor's Office Hours At least Once**
Wednesday, October *20*, 2000:	**Topic Outline Due**
October 23 – November 26, 2000:	**Use Instructor's Office Hours At least Once**
Wednesday, November 29, 2000:	Term Paper Due

PRESENTATION OF TERM PROJECT – DEAD WEEK

Choice of three specific research topics, and start of research project entails knowledge of the subject material, knowledge of the capabilities of the equipment and instruments available in the plastics laboratory, and awareness of the area(s) of research interest. At the one-month point, the student has already performed four laboratory experiments and has some familiarity with the laboratory equipment/instruments and their capabilities. Knowledge of the subject material is enhanced via literature search. It is customary and typical to invite a librarian/expert to demonstrate the library search process[(11)] for the class. Literature search also facilitates generation of ideas or "ideation". Ideation is the "driving force or motivation" for customization, ownership and subsequent implementation of the research project. Ideation and implementation have previously been cited as core elements of critical thinking and creativity. Ownership implies ethical responsibility and accountability for acquired and generated knowledge. The researcher understands the need to verify and validate information and data before usage and the role of the individual in knowledge design, development and creation.

The 3Rs' Process: mentoring, Advisement and Guidance Strategy

A facet of the mentoring, advisement and guidance strategy is "seeding" or "motivation spiking". Student report presentations (representations) are recorded. PSU has a very well equipped recording studio that houses a rich library of previous presentations over the past 10 years. Selected video tapes are shown to the class, and the students are required to critique the presentations as a class assignment. The effect of this is tremendous. The student can see previous students presenting their work. The product is real and tangible. The display of mastery and ownership by some previous students has a "seeding" or "motivation spiking" effect. The student realizes that with good planning and control, quantifiable and authentic results are possible, and that these results are meaningful. Result meaningfulness can be shown via concept, theory and fundamentals-based analyses and interpretation of generated data. The instructor's office hours make it possible to harness the fruits of this "motivation spiking"; the student has a higher level of confidence on his/her ability to participate in the 3Rs' process. The student develops a plan of action and uses the instructor's office hours to validate plan. The instructor fine-tunes and refines the student's plan with respect to feasibility and workability. It is very important to point out especially to the student that not all good plans are feasible and workable under the course conditions of the 3R's process. A bad plan would definitely lack feasibility and workability. This motivation spiking strategy draws from and reinforces our experiences at PSU's department of engineering technology that certain students tend to prefer other students as mentors and tutors. In recognition of this, students of the senior capstone courses are utilized in the lower level lab courses as mentors, facilitators and help. Ofcourse, the senior capstone course students in their capacity as mentors and facilitators are "by doing learn"ing.

Another facet of the mentoring, advisement and guidance strategy is "pre-presentation" that is usually equivalent to one class assignment. Following the due date of the research outline, the class members make a 3-5 minute presentation of their plan of work. This is another opportunity for advisement and guidance and for the class to develop awareness of the research activities of the other members. Awareness of mutual areas of activities presents the opportunity for collaboration and cooperation. Pre-presentation is also rehearsal for report presentation (re-presentation). It gives the student a feel of how to prepare for a successful report presentation. It is the experience of this author that report presentation is usually much better than pre-presentation in terms of preparedness, quality, knowledge and communication skills.

3. The 3Rs' Process: Discussion of Selected Primary Products.

The 3Rs' process is a non-traditional, innovative approach to teaching and learning at the undergraduate level. It involves the elements of organization, knowledge and understanding of the subject material, innovative application of course materials, resourcefulness, intellectual self discipline, focus and deductive reasoning. The correct use of the formal report format takes the student through the process of literature search, design of experiment, performance of experiment, analyses and interpretation of generated and acquired data, technical report writing and report presentation. This correct use of the formal report format, and the associated goal setting such as selection of specific research topic, plan formulation on how to implement selected project and commitment to successfully perform the 3R's process are demonstrations of organizational skills.

Knowledge and understanding of the subject material are displayed in the main body of the paper. For example, the paper entitled: "Thermoplastics in Automotive Bumpers" cites the reasons for the use of plastics as choice materials in automotive bumper applications as, "ease of processing, weight reduction, styling freedom, performance (corrosion resistance, weatherability etc.) and cost-effectiveness." This project also demonstrates the ability to acquire and utilize knowledge; there is appropriate performance of impact strength, low temperature properties and toughness experiments to ascertain which of the selected plastic materials is most suitable for bumper application. This ability to correctly perform experiment for data acquisition comes from knowledge acquired from the laboratory section of the course whereas analyses and interpretation of data come from the concepts and fundamentals of the lecture section of the course. Determination of which materials are most suitable for automotive bumper applications is a display of knowledge of plastic materials and deductive reasoning.

In another research project entitled: "Liquid Crystalline Polymers in the Electronics Industry", the attempt to make injection molded test bars of the high temperature LCP material using a 75-Ton Van Dorn (1980) machine was facilitated by the innovative application of nozzle insulation to achieve the set point nozzle temperature. To show the dimensional stability of the material as required for close tolerance molding of typical electronic parts, the student measured the mold shrinkage of the injection molded test bars.

4. Conclusion

Research, inherently involves planning, organization, control, discipline, and the utilization of one's resources in a focused and directed manner to achieving set goals. Metacognition and innovative application of knowledge are key elements of critical thinking and creativity. Documentation and dissemination of research results require effective communication skills such as technical report writing and report presentation. With report writing, publications and representation, there is a conscious effort directed toward marketing and exchange of ideas with an audience. In essence, dissemination of research findings via report writing and representation involves the development of a commonness of field of experience; commonness of field of experience or "empathic psychological set" has previously been cited as a core element of effective communication. Critical thinking, creativity and effective communication skills are the driving force for productivity, the main stay of civilization.

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