Creativity By Design: CNCMM's RE^{3}AD Program

By

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Abstract

CNCMM [www.cncmm.org], PSU, in collaboration with its academic and industry partners, is currently implementing the ONR-sponsored project entitled: "Multifunctional Materials for Naval Structures." The research and education thrusts of this multi-faceted project provide CNCMM the opportunity for inculcating in its student participants the need for creativity and innovativeness. The pedagogical approach of the CNCMM's RE^{3}AD program is to immerse our participants in active, team-based and mentored learning environments that facilitate the development of skills and proficiencies in the areas of research, education, ethics, entrepreneurship and dissemination. The research and education components are designed for acquisition of knowledge in planned, organized, directed, controlled and disciplined formats that embody "ideation and implementation," the foremost elements of creativity and critical thinking. The ethics, entrepreneurship and dissemination elements complement the participants' critical thinking skills, innovativeness and creativity. A CUES-AM (Consortium for Upgrading Educational Standards - Assessment Model) evaluation of the 2005 CNCMM program yielded a true student satisfaction index (I_{TS}) of 0.80 or very good performance rating whereas an evaluation of the 2006 pilot nanotechnology entrepreneurship course resulted in a true satisfaction index of 0.92, indicating excellent course performance.

Introduction

CNCMM, PSU is an interdisciplinary, coherent, hands-on, nanomaterials-oriented center, and its research activities introduce undergraduate and graduate students to the fundamentals, design, synthesis, fabrication, characterization and modeling of energy absorbing, multifunctional, hierarchical nanocomposites. Comprehensiveness of CNCMM's activities, with respect to students, has resulted in the RE^{3}AD program; research, education, ethics, entrepreneurship, assessment and dissemination. Pittsburg State University is especially committed to involving students in faculty-directed research activities, and CNCMM employs this approach in its workforce development effort. The interdisciplinary nature of CNCMM's research thrusts in nanomaterials necessitates the recruitment of student fellows from the SMET and business programs. This reflects the education component of the RE^{3}AD program. CNCMM's appreciation of TAC-ABET criterion 2i-j, or the "ability to understand professional, ethical, and social responsibilities, and the respect for diversity and global issues," necessitates the incorporation of ethics and entrepreneurship in its program. Creativity is considered as one of the top characteristics of the entrepreneur [Min 1999]. Funding agencies such as ONR, NSF, NCIIA, and accreditation agencies encourage and require the assessment and dissemination of research findings.

Dorf and Byers [Dorf 2006] define creativity as the ability to use imagination for developing new ideas, new products or new solutions. This author defines creativity as ideation plus implementation; 2i = S. Where i is ideation or implementation and s = success. Joanne Gaine Kurfiss' foremost definition of critical thinking [Kurfiss 1990] identifies metacognition and the innovative application of acquired knowledge as the bases for creativity. Creativity and innovation are the "driving force" for industrial and societal productivity, as represented by the GDP (gross domestic product) and GNP (gross national product). In a much earlier publication, Dorf cited productivity as the leading criterion for civilization [Bloom 1956].

The objectives of this paper are to:
1. substantiate the school of thought that creativity can be developed and acquired, and
2. demonstrate the viability of CNCMM's RE^3AD program for creativity acquisition.

CNCMM's RE^3AD Program Profile: Activities and Timelines

The research and training activities that are used by the RE^3AD program include:

i. Availability of research activities in all areas of science, mathematics, engineering and technology. PSU-CNCMM research and program participants are allowed to choose three research topics and advisors; they are then successfully matched with activities in the areas of their choice and preference, and are assigned to a research topic/advisor. Ownership and pride of ownership are key ingredients for a successful undergraduate research experience [Ibeh 1999]. CNCMM fellows are recruited on a year-long basis rather just for the summer; research and project activities initiated during the summer are continued during the regular semesters.

ii. The student participants are required to enroll in 3 hours of academic credit in "Research Methods". This prepares the participants for research work and reinforces the "hands-on" training provided by the PSU-CNCMM program activities. Courses taught under this designation include "Laboratory Safety," "Research Topics in Nanocomposites," "Nanomaterials & Energy Management," "Research Topics in Polymers and Plastics" and "Nanotechnology Entrepreneurship." These courses are co-taught by the faculty advisors of the program, and complemented with invited industry speakers as the situation calls for. Course provides student participants a value-added research and education experience.

iii. An initial training period during which the PSU-CNCMM participants are educated on how to conduct research and specifically how to carry out their assigned research activities with emphasis on laboratory safety. First on the activity agenda for the student-participants is conferencing with their assigned research faculty advisor. The objectives of this first participant/faculty conference is for the faculty to review the level of participant's preparation and to inculcate in the participant(s) the program goals. Specific personal goals for the research experience are also set at this meeting. Goals set at this meeting are used as criteria for the evaluation segment at the end of the summer. (The different groups are encouraged to keep a summary sheet of goals.) This initial meeting is followed by a customized, "hands-on" training period of about one to two weeks, during which the faculty advisor shows the participant(s) how to appropriately utilize the relevant equipment and instruments.

iv. A 1-3 hours, weekly meeting (time of day determined by each group) of the faculty advisor and the participant(s) of his research team. The advisor and the participant team review and discuss work already performed and what needs to be done to successfully implement their research project. The advisor directs the discussions such that the student(s) have ease in carrying out tasks such as design of experiment, data acquisition, data analyses, report writing and presentation.

v. An outlet or medium for expression and exchange of ideas and techniques such as a weekly general seminar that is attended by all the participants of the program. This forum serves to introduce participants to the concept of public presentation. PSU-CNCMM participants are required to make presentations on their on-going research, their findings and impact of their results. Participants and advisors critique each presentation and suggest possible areas of improvement. The weekly seminar also includes a series of lectures and interactive workshops by guest/faculty speakers on a variety of topics such as "technical report writing techniques", "literature search techniques", "red cross CPR techniques", "presentation (power point) techniques", "ethics in industry", "industry experiences round table discussions" etc. These presentations take place during the weekly seminars except for the "red cross CPR" workshop that is arranged by Dr. Blatchley via the local Red Cross unit.

vi. The first four weeks of the site's summer weekly seminar program is devoted to ethics study. The participants are introduced to the concept of ethics via the use an ethics panel consisting of Dr. Virginia Rider, bioethics; Dr. Michael Muoghalu, business ethics; Dr. Dilip Paul, safety & environmental ethics; Drs. Oliver Hensley and Marjorie Donovan, general ethics; Dr. Gary McGrath, religion & ethics; Dr. Chris Ibeh, program director. The participants work on ethics case studies in teams and individually. The participants present their ethics projects at the ethics symposium during the sixth or seventh week of the summer [http://www.cncmm.org/workforce.html].

vii. A few (at least two) picnics typically organized by the project director, designed to generate interaction among the student-participants and the dedicated faculty advisors. Other members of the PSU community are invited too to help make the CNCMM participants feel welcome and comfortable in Pittsburg. The informal setting of this get-together facilitates networking especially in the areas of tools and techniques for effective research.

viii. A series of field trips and plant tours to local and surrounding companies and industries such as 3M Corp, Nevada, MO, Eagle Picher, specialty battery manufacturer, Joplin, MO, Able Manufacturing Corp., Joplin, MO., DeGussa Fine Chemicals, Galena, KS, Cessna Aircraft Co., Independence, KS, Chevron-Phillips Petroleum Research and Development Center, Bartlesville, OK, Kustom Signal Inc., Chanute, KS, Wolfcreek Nuclear Power Plant, Burlington, KS, Pittsburg City Water Treatment Plant and others, to acquaint PSU-CNCMM participants with real world, industry-based activities, and the role of research in industry and society.

ix. A campus-wide final symposium during which CNCMM participants present their research work to PSU students, administrators and their families and friends. The reports submitted by the participants on their work are published in the CNCMM Site proceedings. Participants research abstracts and ethics reports can be found on our website via the URL: http://www.cncmm.org/workforce.html. An on-site laboratory presentation, midpoint during the summer program acquaints the group of the individual participant's work, and helps prepare the participants for the campus-wide symposium.

x. Attendance of regional, national meetings of professional organizations such as Society of Plastics Engineers, American Chemical Society, American Physical Society, American Institute of Chemical Engineers, Society of Women Engineers, American Society for Engineering Education, NCIIA, International Conference on Composite/Nano Engineering, etc. PSU-CNCMM participants are encouraged and sponsored to attend these meetings, and make presentations to disseminate program's research findings.

CNCMM's Research

CNCMM's research thrust is in three major and inter-related areas of design, synthesis, fabrication, characterization and modeling of:

i. energy absorbing, multifunctional, hierarchical nanocomposites,
ii. mixed metal oxides nanoparticles, and
iii. nano-engineered luminescent sensors.

i. **Energy Absorbing, Multifunctional, Hierarchical Nanocomposites [Ibeh 2004]**
CNCMM's design and fabrication of hierarchical nanocomposites for blast mitigation and energy dissipation applications are materials selection and quality control-dependent as there are the needs for careful choice of starting materials [Fangling 2004] with the right properties and characteristics, and the appropriate processing windows. CNCMM's conceptual designs [Figure I] of blast mitigating, multifunctional materials and structures are based on the principles of absorption and redistribution of locally concentrated high load energy to a larger volume of material, and temporary conversion of part of the blast load energy to kinetic energy of some structural elements interacting with external loading. This kinetic energy is in turn converted to the energy of deformation of part of the material and structure. This allows for the extension of the loading process to a larger time frame, with consequent decrease of load level and blast load mitigation. Converted and redistributed energy can be dissipated using the intrinsic, viscoelastic properties of the constituent materials.

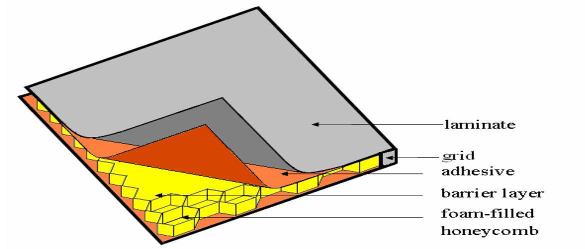


Figure I: CNCMM's Conceptual Design of Multifunctional 3-D Nanocomposite Sandwich.

Processing and fabrication involve validation of each process technology such as materials and components cutting technology [laser, water jet, diamond knife etc], fabrication technology [compression molding, VARTM, VAHLUP] parameters (processing window). Characterization [Sun 2004] efforts involve morphology determination [AFM, TEM, DSC, etc], static and dynamic mechanical measurements of stress-strain properties with emphases on structural stiffness, dimensional stability, toughness etc.[universal testing machine], and flammability resistance [cone calorimetry (FTT), horizontal and vertical burn tests]. Preliminary results indicate that nanocomposites-filled honeycombs have very good potential as sandwich cores for enhanced mechanical properties and are very good prospects for energy dissipation and blast mitigation.

With respect to low density foam-filled honeycombs, the summation rules for strength and for Young's modulus apply. For higher density foams, this rule does not apply, and a sharp synergistic effect is observed [Table I]. This synergy occurs as the foam carries part of the total compressive load in addition to other mechanical functions such as: i). support of the walls of honeycombs as an elastic foundation with increase of their critical buckling load, and (ii). formation of quasi-monolithic layers on the walls of honeycombs, and conversion of the walls' structure to a sandwich-like structure with increase in bending stiffness and resistance to buckling of the walls. Modeling of the elastic supporting effect by foam shows that the compressive strength of the foam-filled honeycombs can be estimated according to the formula [Beyle 2007]:

$$\left|\left\langle \Pi_{3(-)}^{(h)} \right\rangle\right| = K \frac{\pi^2 D_2}{b^2 h^{(w)}} c \quad \text{.......} (1)$$

Where b is the size of the honeycomb cell, $h^{(w)}$ is the height of the honeycomb wall (thickness of the core), D_2 is the honeycomb wall's bending stiffness in the plane perpendicular to the core and to the wall, K is a coefficient that depends on the interaction with the neighboring wall and onYoung's modulus of the foam; c is the volume part occupied by the walls of the honeycombs. Successful project implementation involves validation of materials' morphological and mechanical characteristics with respect to compressive, tensile and shear stress-strain profiles. Specific and current goals of this project are to: i). develop fire resistant nano-enhanced materials, ii). determine the mechanisms for improving blast resistance, iii). model behavior and performance of blast resistance structures, and iv). develop nano-enhanced blast resistant materials.

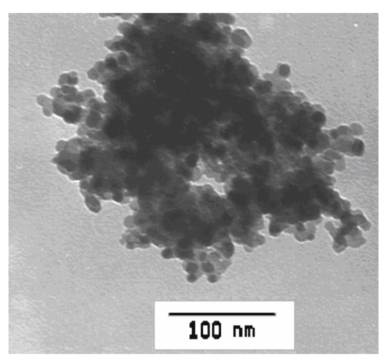
Property\Material	*Honeycomb*	*Honeycomb with foam* *Foam 2*	*Honeycomb with foam* *Foam 4*	*Honeycomb with foam* *Foam 10*
Density (kg/m^3)	94.2 (2.83%)	138.4 (2.21%) 50 (13.4%)	161.7 (2.34%) 68.9 (5.32%)	204.7 (5.84%) 90.9 (5.94%)
Compressive strength (MPa)	4.55 (6.45%)	4.90 (7.0%) 0.345 (26.5%)	4.96 (10.0%) 0.483 (23.0%)	7.03 (5.0%) 0.90 (8.0%)
Young modulus (MPa)	39.8 (2.52%)	45.3 (7.0%) 2.42 (35.6%)	48.6 (12.0%) 2.63 (41.0%)	101.7 (8.0%) 13.5 (32%)

Table I: Mechanical Properties of Honeycombs, Foams, and Foam-filled Honeycombs[25][26][27] with the Coefficient of Variation for each Property in Brackets.

ii. **Mixed Metal Oxides Nanoparticles: Design, Synthesis of High Surface Area, A.P. 2%Cr-$SrTiO_3$ and A.P. 2.5%Sb -2%Cr-$SrTiO_3$ Nanoparticles** [Madhavaram 2004]

This project involves the formulation, synthesis and characterization of nanonoparticles by a wide selection of metal precursor and proper solvent removal techniques with emphasis on the preparation of high surface area and highly reactive nanoparticles. Effort on this project is currently being carried out under three titles: (a). "Synthesis and Characterization of A.P. 2%Cr-$SrTiO_3$ and A.P. 2.5%Sb-2%Cr-$SrTiO_3$ Nanoparticles and Their Applications Towards Adsorption and Decomposition of Acetaldehyde," (b). "Synthesis and Characterization of Cr-AlMCM-41 and Its Application toward Photo-catalytic Decomposition of Acetaldehyde," and (c). "Solid-State NMR, TEM and DUTM Characterization of In-lab Formulated Nanocomposites." The synthesized nanoparticles are characterized by different physical and chemical methods such as powder x-ray diffraction, surface area measurements, transmission electron microscopy, and hydroxyl/carbonate species determination via FT-IR. Drying and calcination play an important role in affecting the physical and chemical properties of nanoparticles, hence controlled dehydroxylation and calcination is carried out using a combination of FT-IR and mass spectroscopic techniques. Table II and Figure II show the higher level performance of in-lab produced AP-$SrTiO_3$ (aerogel prepared) nanoparticles, and the potential for significant modifications of the physical and chemical properties of the nanoparticles. This will facilitate formulation and preparation of nanocomposites with desired properties [Ray 2006].

$SrTiO_3$ sample *	Crystallite sizes, nm	Surface area, m^2/g	Total pore volume, cc/g	Avg pore size (d), Å
CM-$SrTiO_3$	145	1.0	0.003	93
NCM-$SrTiO_3$	25	17	0.12	290
AP-$SrTiO_3$ (Methanol	25	82	0.58	280
AP-$SrTiO_3$ (Ethanol)	8	159	0.62	150
AP-$SrTiO_3$ (Isopropanol	20	121	0.59	190



Textural Properties of SrTiO3 : (A). Table II and (B). Figure II : AP- SrTiO3 calcined at 500°C
CM – commercial, NCM – commercial nanosized, AP - aerogel prepared samples

It is planned to expand the thermal and photochemical reactivity of these nanomaterials to more compounds with environmental concerns and of DOD's interest.

iii. **Design, Synthesis and Characterization of Nano-engineered Sensors**

This project involves the design, synthesis and utilization of mesoporous silica materials in film form, which contain stabilized silicon atom clusters of 2 nanometers size or less. The very small, nanometer size of the silicon clusters makes them suitable for embedment in energy dissipative nanocomposites matrices without significant effects the mechanical characteristics of the host matrix. They are capable of electroluminescence when the appropriate current or voltage is applied, emitting fast photons with nanosecond lifetimes [Ozin 1990]. Electroluminescence, as well as photoluminescence, has been demonstrated in many devices by the use of porous silicon, which can reach 5% quantum efficiency, but has serious problems with respect to fragility, short degradation times and integration into microelectronic circuitry [Canham 1990]. Also the large size of the silicon units in porous silicon(2-50 nanometers) produce emission times in the millisecond to microsecond range, which is too slow for use in LED's [Canham 1990]. However by producing silicon clusters of 2 nanometers or less, significantly different electronic properties are achieved, in terms of significantly faster photons for photoluminescence, electroluminescence and photoelectronic applications.

The major problem with constructing viable nanosensors is producing mesoporous films with the correct morphology, ie: hexagonal structure, as opposed to cubic, lamellar or random structures. This project provides a method of preparing photoluminescent materials that are capable of producing fast photon emissions as well as practical applications for naval structures, such as the hulls of ships, submarines and body armor. Inorganic and electrically insulating materials, which contain in their pores stabilized clusters of silicon atoms that are 2 nanometers or less in size are necessary for emission of fast photons [Ozin 1990]. Since most mesoporous materials are obtained as fine powders as a result of the biphasic medium, thin films may be produced by use of a homogeneous (monophasic) medium which is accomplished by using a surfactant, such as Brij-56, greater than 30% by weight of the total solution [Yang 1996]. A powder X-ray diffraction pattern is used to show the hexagonal mesoporous silica structure, while FTIR microscopy spectra displays bands of surface silicon clusters [Shirley 2003]. Also solid state Magic Angle Spinning 29 Si and 1 H NMR, as well as FT-Raman and IR Spectra are used to indicate the presence of surface-passivated silicon clusters in the mesoporous silica film.

CNCMM's Education and EntrepreneurshipThrusts

CNCMM is developing a graduate materials program with emphases in nanocomposites, computer proficiency and entrepreneurship [Ibeh 2007]. To date, work has involved a thorough survey and evaluation of available materials "science and engineering" programs nationwide. Based on the committee's findings, a database of universities offering "materials science and engineering" programs has been developed. With this, a list of subject areas common to materials science and engineering programs has been delineated, and these include but not limited to:

i. Innovations in Materials Science and Technology,

ii. Characterization and Testing of Nanocomposites/Nanomaterials,
iii. Modeling and Simulation Methods for Materials Science and Technology,
iv. Physics of Nanocomposites/Nanomaterials,
v. Mechanical Behavior of Nanocomposites/Nanomaterials,
vi. Thermodynamics and Kinetics of Nanomaterials,
vii. Processing of Nanomaterials/Nanocomposites,
viii. Energy Absorption Characteristics and Joining of Nanocomposites,
ix. Chemistry of Nanocomposites/Nanomaterials,
x. Special Topics,
xi. Design and Selection of Nanocomposites and Multifunctional Materials,
xii. Entrepreneurship in Nanotechnology,
xiii. Safety, Ethics and Environmental Issues of Nanocomposites/Nanomaterials, etc.

As part of an NCIIA-sponsored project entitled: "Design, Development, and Implementation of a Nanotechnology Entrepreneurship Three-Course Series at PSU," three nanotechnology entrepreneurship courses entitled: "nanotechnology entrepreneurship," advanced nanotechnology entrepreneurship," and "strategic product development" are under development. The first course will be offered to the CNCMM fellows in the spring semester of 2008 whereas the second and third will be offered in the summer and fall semesters respectively. In the interim, while these courses and program are under development, the CNCMM student fellows obtain their studies and degrees from their host departments and disciplines; CNCMM is interdisciplinary, and its sponsored student-fellows come from SMET and business departments and programs. CNCMM recruits and sponsors its student-fellows on a yearly basis. The students do research internship with CNCMM during the summer months but do academics and research during the regular semesters; PSU policy requires the research graduate assistants do a maximum of 20 hours per week of research work.

CNCMM's Ethics program

The first four weeks of the CNCMM's summer weekly seminar program is devoted to ethics study. The participants are introduced to the concept of ethics via the use an ethics panel. The Friday, weekly seminar meets for 3 hours. The student participants are introduced to the ethics panel and to the concept of ethics via definitions and example situations; Enron, Worldcom, etc. are notable examples. The ground rules are specified, and the report writing format is presented and explained in detail; this is crucial considering that the participants are required to do two reports, ethics and research for the summer program. The participants are put in teams, and presented with an ethics case study; the 2007 case study was on a company whose plant is depositing a high levels of lead into the community's sewage. The groups were assigned to analyze the situation from different perspectives such as "codes of ethics," "safety," "environment," "moral framework," "globalization," etc. Team presentations are critiqued by the panel and student participants. With the feedback and guidance of the panel, the various teams produce a final position document that is presented to the whole group. In the second and third weeks, the groups progressively move towards individualized ethics work; each participant chooses three specific topics of interest; the participant is assigned an ethics topic. The participant works with the guidance of the panel to produce an ethics paper. This paper is presented to the group at the program's ethics symposium during the fifth or sixth week of the summer program. Scheduling of the ethics symposium allows for transition of focus to the research project.

Assessment

CNCMM, PSU is currently the home of CUES-AM; an online assessment protocol. CUES, Consortium for Upgrading Educational Standards, is the brainchild of Dr. Oliver Hensley, coordinator of the PSU specialist in education program and member of CNCMM's advisory council [Ergish 1997]. This author is the developer of the satisfaction index, CUES-AM's rating scale [Ibeh 2004]. CUES-AM also provides the report writing format for the CNCMM program [Ibeh 2002]. CNCMM's assessment efforts reflect the need for accountability and standardization as required by funding and accreditation agencies. Also, CNCMM's efforts to design and develop a nanotechnology entrepreneurship curriculum require an in-built continuous improvement protocol that complements the entrepreneur, and facilitates the acquisition and development of creativity and other desirable entrepreneurial attributes. CNCMM participants are apprised with the mechanics of the CUES-AM protocol in regards to the expertly, pre-determined, site-specific program attributes – essential knowledge elements (EKEs) and the EKE factors such as efficacy, validity, comprehensiveness, interest, usefulness and difficulty, and how they are utilized to evaluate program's participants satisfaction level.

Table III: Satisfaction Indices of 2005 CNCMM Program Activities [Ibeh 2004]

Activity [EKEs]	E_F	D_F	I_D	I_S	I_{TS}
The Wednesday Afternoon Classes (Nanocomposites)	7.200	7.420	0.048	0.720	0.768
The Friday Afternoon Classes (Ethics/Seminar)	6.616	5.420	0.048	0.662	0.670
The Picnic	7.000	4.920	0.048	0.700	0.698
Lab Experience	8.664	7.670	0.048	0.866	0.920
Availability of Principal Investigator for Lab Experience	8.400	8.080	0.048	0.840	0.902
Ethics Paper Experience	6.900	6.170	0.048	0.690	0.713
Research Paper Experience	7.950	7.500	0.048	0.795	0.845
Writing the Ethics Paper	6.684	6.250	0.048	0.668	0.693
Writing Your Research Paper	8.166	7.420	0.048	0.817	0.865
Liaison Activities	7.100	6.170	0.048	0.710	0.733
Time With Your Mentor	8.052	7.170	0.048	0.805	0.849
Creating New Materials	7.632	7.750	0.048	0.763	0.818
Internships	7.184	6.830	0.048	0.718	0.755
Repairing, Using and Calibrating Equipment	8.050	7.420	0.048	0.805	0.853
Securing Materials, Supplies, Reagents, Samples, Documentations	7.616	6.420	0.048	0.762	0.790
Field Trips	6.776	5.550	0.048	0.678	0.689
Overall	7.499	6.760	0.048	0.750	0.798

Tables III and IV have the EKEs, EKE factors and satisfaction indices for the CNCMM 2005 program and 2006 nanotechnology entrepreneurship course respectively. Tables III and IV indicate true satisfaction indices of 0.80 and 0.92 for the 2005 CNCMM program and 2006 pilot nanotechnoloy entrepreneurship course respectively.

Table IV. CUES-AM Assessment of Pilot Nanotechnology Entrepreneurship Course [Summer2006][Ibeh 2004]

CUES Checklist EKE	Usefulness 1 to 10	Interest 1 to 10	Comprehensiveness 1 to 10	Difficulty 1 to 10	Validity 1 to 10	Efficacy 1 to 10	Average
Topics Covered:							
Introduction to Entrepreneurship	8.8	9	9.2	6.8	9.2	8.8	8.63
Entrepreneurs: characteristic, risk, stress, personality test	8.6	8	7.8	6.6	7.8	8.4	7.87
Creativity	9.2	9.6	8.6	5.8	9.2	9.4	8.63
Financial Planning	8.4	8.2	8.8	6.8	8.8	8.8	8.3
Business Plan	9	8.8	8.8	7.2	8.8	8.8	8.57
Venture: types, sources of capital and Intellectual property	9.2	8.4	8.6	7.2	8.6	8.6	8.43
Entrepreneurial Sweet Spot	7.8	8.2	9.6	5.6	8.4	9.2	8.13
Other Activities:							
Clippings Presented in the Class	9.5	9.5	8.5	7.5	9.5	8.5	8.83
Overall impression of the course	9.2	8.6	9.4	6	8.6	8.8	8.43
Interaction inside the Class	9	9	9	7.6	9	9	8.77
Assignments	9.6	9	9.2	7.8	9	8.6	8.87
Average	8.94	8.75	8.86	6.81	8.81	8.81	8.50
$I_S = (\sum E_F)/5 = 0.885$; $I_D = 0.2[(6.81-5)/10] = 0.0362$; $I_{TS} = I_S + I_D = 0.92$							

Dissemination

CNCMM encourages and supports dissemination activities of its participants. The intra team and individual reports and presentations of the participants during the program's ethics workshops, weekly seminars and symposia facilitate active acquisition of effective communication skills. These efforts are complemented and supplemented by the conference proceedings and journal publications of the participants. Some of CNCMM's current dissemination activities include but not limited to: "Trends in Nanocomposite Foams," Polymer Foams Conference, October, 2007; "Research and Education at CNCMM, PSU," ASEE-MW Regional Conference, September 2007; "Energy Absorbing Polymeric Nanocomposite Sandwich Structures in Blast Mitigation," ONR-Solid

Mechanics Conference, September 2007; "A Pilot Nanotechnology Entrepreneurship Course at PSU," ASEE-National Conference, June, 2007; "Development of New Biodegradable Materials Via Blends," GPEC, March 2007; "Flammability Resistance Properties of Epoxy Nanocomposites," ASME, November 2006 and others. The reference section of this article cites some of the numerous publications of CNCMM. In addition, several CNCMM program participants have achieved MS and BS degrees in engineering technology, physics, chemistry and business administration. Two CNCMM staff members have attained their Ph.D degrees as part of the PSU-UNO partnership and collaboration.

Conclusions

This paper demonstrates that creativity can be developed and acquired; CNCMM's pedagogical approach of immersing its participants in active, team-based and mentored learning environments has evolved into the RE^3AD program. The RE^3AD program facilitates development of skills and proficiencies in the areas of research, education, ethics, entrepreneurship, assessment and dissemination. The ability of CNCMM participants to engage in meaningful and productive research and education activities validates CNCMM's approach.

Tables III and IV indicate true satisfaction indices of 0.80 and 0.92 for the 2005 CNCMM program and 2006 pilot nanotechnology entrepreneurship course respectively, and demonstrate viability of CNCMM's RE^3AD program for creativity acquisition. The student-participants understand the need for accountability, ethical and social responsibility, and have a demonstrated appreciation of the usage of the CUES-AM performance evaluation protocol.

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