INNOVATIVE CONCEPTUAL ENGINEERING DESIGN (ICED): CREATIVITY AND INNOVATION IN A CDIO-LIKE CURRICULUM

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ABSTRACT

Innovative Conceptual Engineering Design (ICED) is a proposed methodology for infusing creative problem solving and innovation within a team-oriented, problem-based learning program. Implementation of the ICED methodology in this specific program attempts to solve several critical problems facing science, technology, engineering, and math (STEM) education and STEM-related careers in the US such as: the decline in enrollment and achievement in STEM degrees and careers and the early attrition of undergraduate students from STEM programs of study. The ICED program is an integrated approach to teaching basic engineering concepts and problem solving techniques focused on solving real-world, epic challenges facing society. These complex, multidisciplinary challenges provide the inspiration and integrated curriculum for multiple years of study. Results are presented for several instances of ICED courses ranging from high-school to young practicing engineer focused on space exploration challenges currently facing NASA.

KEY WORDS

Problem-based learning, Innovative Conceptual Engineering Design (ICED), Intelligent Fast Failure (IFF), rapid development, rapid prototyping, critical thinking

INTRODUCTION

The United States leads the world in annual spending per school-age child yet ranks 10th in math and 9th in science out of 12 countries in Asia, Europe South America and North America [1]. One explanation could be that while there are hundreds of programs offered in any given STEM field, there is very little integration between these programs with larger academic requirements, skills and standards. In addition, most programs focus on the attainment of skills within one or possibly two disciplines with very little, if any, connection between the multitudes of skills required to solve real problems that may be of high personal interested to the student.

The Innovative Conceptual Engineering Design (ICED) methodology is a result of over 37 years of experience in solving complex engineering problems at NASA, and over eight years of experience in teaching and field testing ideas compiled from experiences; at the practicing engineer, university faculty, and graduate, undergraduate and high-school student levels. ICED is centered on the solution of *real*, critical science-, engineering-, and/or technology-based multidisciplinary problems. Its focus and emphasis on the conceptual phase of design is for two strong reasons: the conceptual phase is the best time to radically impact the successful outcome of a project; and it is also the best time for engineers to exercise their creative dimension or "right-brain" and experience the associated joy it brings. In fact, most large, bureaucratic institutions such as NASA, and many large companies tend to stifle the creative process by reducing the time spent in the conceptual phase and down-selecting too early; resulting in solutions which are grossly sub-optimal and/or infeasible, resulting in significant cost overruns and/or program cancellation.

The ICED methodology draws upon a *diverse* group of students to exercise the analytical/logical/structured side of their brain (the left hemisphere) and its associated skills as well as the artistic/creative/innovative right hemisphere to explore an open-ended design space, conceive ideas and *develop* innovative solutions. The primary purpose is to attract and inspire students to the joy of solving "real" and very interesting engineering problems while maintaining that interest and passion throughout the educational experience. This is accomplished by: 1) functionally decomposing the complex problem into fundamental concepts in science and engineering, 2) developing age-appropriate lessons in each of the necessary STEM subject areas, and 3) by linking the mastered STEM skills to the next level of knowledge/learning as needed to solve the problem. It is this bridging of educational concepts from high school to undergraduate and graduate education which provides the internalized connection and linking of educational concepts to problem solving and hands-on experiential learning. We propose this approach as a means of maintaining continued interest and passion in science, engineering, and learning in general.

The methodology relies on problem-based-learning very similar to Conceive, Design, Implement, and Operate (CDIO) [2] and uses a collaborative environment which emphasizes teamwork, team learning, rapid prototyping, collaboration, cooperation, and communication. It also relies on a virtual platform to link students to mentors, technical experts, and resources from around the world (Academia, Industry, and government). This platform will effectively provide mentorship at age-appropriate educational levels, and accelerate problem solution and concept maturation so intelligent design decisions can be made early in the design cycle. It is hoped such a program can inspire the next generation of scientists, engineers, mathematicians, innovators and entrepreneurs.

While CDIO encompasses the entire "life-cycle" design process and incorporates C-D-I-O elements, ICED focuses on the conceptual design portion as the most creative phase – the one phase which can offer the most leverage for success. ICED is also distinct in several other ways: 1) it is designed to function across multiple age/maturity/experience levels, 2) it relies on distance learning and web-based tools, and 3) it is funded by sponsors who support the "epic" challenge, rely on its solution and have a vested interested in developing a pipeline of high performing students that have a passion for that particular industry/enterprise.

The current paper describes the ICED methodology; presents results and lessons learned at each stage of program development [3-5]; and concludes with future plans and development ideas for scaling such a program globally. It also presents a proposed program organizational structure and operational framework that ensures a continuous stream of mentorship from subject matter expert (SME) to faculty/educators and their students (graduate to middle school).

ICED METHODOLOGY

The ICED methodology is based on the creation of psychologically-safe virtual and physical environments to solve real-world engineering problems. Throughout this process, students are encouraged to explore, experiment, fail, discover, and learn. It is a program where critical thinking and the questioning of ideas, concepts and even "established" facts and theories is celebrated. The methodology draws upon the teaming of very *diverse* groups of students, engineers, scientists, designers, artists, etc. to explore an open-ended design space. Through this process, students will exercise both the analytical/logical side of their brain (the left hemisphere), as well as the artistic/creative/innovative right hemisphere to conceive and *develop* innovative solutions.

As mentioned earlier, the ICED methodology focuses on the very early "conceptual design" phase of the design process. This allows rules regarding the level of rigor involved in the analysis, design, and test phases of the development cycle to be relaxed in order to intelligently and rapidly conceive, prototype, evaluate and mature as many ideas as possible. This consequently allows for potential failure mechanisms to be identified and addressed early in the design process. The idea for teaching and utilizing this methodology for project-based learning and STEM outreach was inspired by work to identify the cause of the Space Shuttle Columbia accident [6], and to develop technologies to predict and repair critical damage to the vehicle in the event of a subsequent debris strike prior to landing [3,4]. Ideas to repair a damaged wing leading edge were rapidly developed and matured using this methodology and flown on the Return-to-Flight Space Shuttle mission following the Columbia tragedy [6] (STS-114) and all subsequent Shuttle missions.

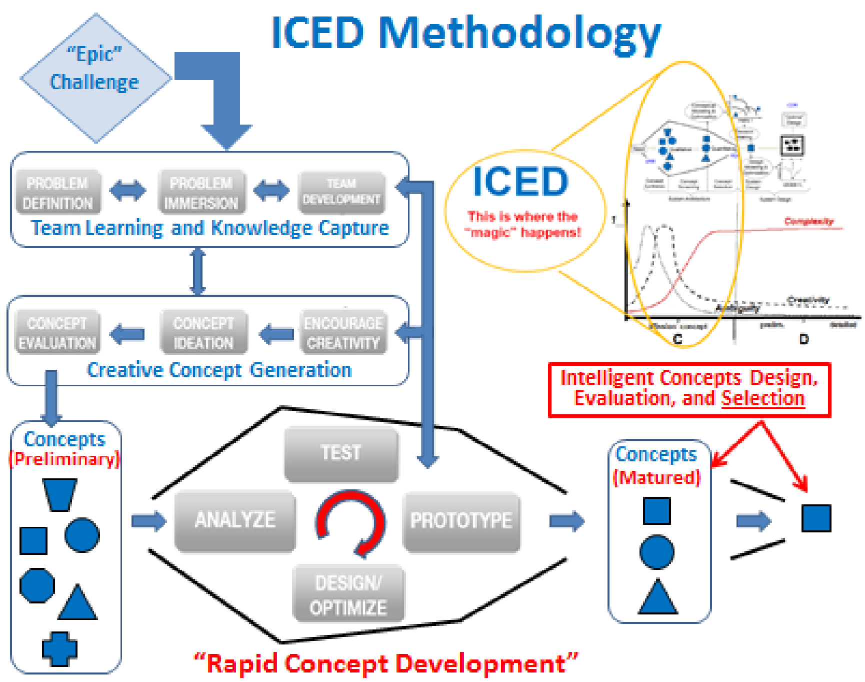

Figure 1. Schematic diagram of the Innovative Conceptual Engineering Design (ICED) process for solving *"Epic"* problems/challenges and its relationship to the product development cycle.

The framework for the methodology, as illustrated in Figure 1, begins with an *"Epic"* challenge or problem which has very special qualities that spark the imagination, create passion and maintain the interest of a diverse community of people dedicated to the development of creative solutions. An example of an *"Epic"* challenge mentioned above was the development of a system to repair a Shuttle wing leading edge by spacewalking astronauts on orbit. Several other examples will be discussed in later sections.

Team members are selected to ensure a diversity of thought, capability/skill, experience, culture, outside interests, etc. to maximize the creativity and innovation of the team's contributions to the solution process. A survey was developed and used to evaluate participant's learning and thinking styles [7-9], creative ability and roles most preferred in the creative process. Similar techniques used at Stanford [10] in forming teams based on "cognitive modes" rely on Myers-Briggs Type Indicators (MBTI), and have shown to be effective in increasing the percentage of successful design awards to teams in the Design Division of Stanford's Mechanical Engineering Department.

Next, the team is totally immersed within the problem and given the overall program/mission goals at the very top level. This allows students to visualize the end goal and recognize the "systems" nature of the problem – one with all its many complex interdependencies. Virtual communities are established to link age-/skill-appropriate student teams to mentors, experts, and resources (e.g., learning modules; hardware; modeling, analysis, simulation and design software; test facilities; etc.) to facilitate team development, learning and leadership and to allocate roles and responsibilities. Various virtual platforms and methods for collaboration have been evaluated. Online lectures were recorded with the intent to develop learning modules to allow self-instruction and mastery of essential skills. These are similar to other online learning platforms such as the Khan Academy [11] or edX [12]. Moreover, digital textbooks called "FlexBooks" (CK-12 Foundation [13]) have been employed, as well as enhanced simulation and modeling tools similar to Reference [14] (which can also be embedded within the FlexBooks). In the longer term, we plan to develop the capability to automatically customize learning modules based on the individual thinking and learning styles of the student [15] using the student survey mentioned above.

Techniques for lateral thinking, creativity enhancement and concept ideation are taught, utilized and include but are not be limited to: brainstorming, SCAMPER, Fishbone Diagrams, 6-3-5 Method, Biologically Inspired Design (BID), and TRIZ [16-21]. Although the program focuses on the early or fuzzy front end of the innovation process, a *"rapid development"* strategy for technology verification, validation, and maturation is established. This is based on rigorous engineering procedures whereby analysis is correlated to experiment in a stepwise, building-block fashion. With time, the solution grows in form, function and complexity. The projected speed and diversity of this process will enable rapid evaluation of a large pool of creative ideas and potential solutions simultaneously, thus enabling more intelligent design decisions earlier in the programmatic cycle, when it will have the largest impact on positive outcome.

REVIEW OF FORMAL ICED PROGRAMS AND CHALLENGES

Table 1 is a concise summary of the formal course offerings of the ICED program from the first class held for NASA engineers in 2008 to the most recent program offered in 2012 at MIT for high-school teachers and students from Boston, Houston, and New Jersey. The following sections summarize these instances of the ICED program as well as lessons learned.

Table 1. History of Formal ICED Programs and Challenges (2008 – 2011)

"Epic" Challenge	Year	Participants	Virtual Platform	Comments
Alternate Land Landing of the Orion Capsule	2008	30 NASA Engineers, 2Grads	Wiki	Numerous ideas, one selected for follow-on
	Follow-on (2008 – 2011)	1 MS, 8 Undergrads	None	**Feasible solution** and best Capstone Project
Digging and Drilling on the Surface of the Moon	2009	1 Grad, 19 Undergrads, & 10 HS students	Blackboar d	Many interesting ideas Led to Lunabotics entry & most Creative Design award
Design of a Spacesuit for Mars	2010	44 HS students	myPort80	Over 40 high schools in the NY/NJ area
Smart Biomedical Sensors for Space	2010	8 NYU Faculty, 2 Grads	myPort80	Think-tank to promote interdepartmental collaboration Many ideas, one potential patent
Autonomous Vehicles to Explore Lava Tubes on Mars	2011	78 high-school students	iQ4	Collaborated with USAF and over 40 high schools
Sustaining Humans on Mars – Habitat Design	2012	3 Grads, 5 Undergrads, 30 high-school students	iQ4 and Google Products	Follow-on formal and informal HS programs (~140 students) Lesson Plans, Khan-style videos, concept maps, and CK-12 FlexBooks developed

Alternate Land Landing of the Orion Capsule (PSU - 2008)

The ICED methodology was initially taught as a formal summer short course as part of the NESC Academy Program in July 2008 to help instruct NASA engineers in the art and science of innovative engineering design [1]. Participants were challenged to develop alternative concepts to a problem that NASA engineers were facing at the time – how to safely land a spacecraft capsule and crew on land while constrained by the same mass and volume that had forced an earlier decision to land on water. A team of university professors from MIT, Penn State, and Georgia Tech were teamed with landing dynamics, human physiology, spacecraft controls, creativity and innovation; and landing load attenuation experts from NASA to create the course content. Working together with training specialists from Ciber Corporation and the National Institute for Aerospace (NIA), the leadership team created all the workbooks, teaching and learning modules and tools; computer models, etc. used during the 5-day class. A diverse group of 30, mostly junior, NASA engineers and scientists were selected from 7 of the 10 NASA field centers across the country to attend the course, which was held at Penn State University [4].

A follow-on study of only one concept generated by the one-week workshop, a personal airbag [5], was funded by the NASA Engineering and Safety Center (NESC). The study included a collaborative team of undergraduates from Penn State and MIT and one graduate student from MIT and lasted a little over 2 years. The team used a three-level Spiral Model for conducting step-wise building-block drop testing (Figure 3(b).) of single airbag and multi-airbag/seat/test dummy systems, whereby analyses were correlated with experimental results at each phase. The results of 38 drop tests indicated that an airbag-based impact attenuation concept is a feasible solution to a problem that was heretofore unsolved by NASA and industry for over 50 years. In addition, the system resulted in a 36% mass savings without crew and an increase in internal capsule volume of 26% (see fig. 3)!

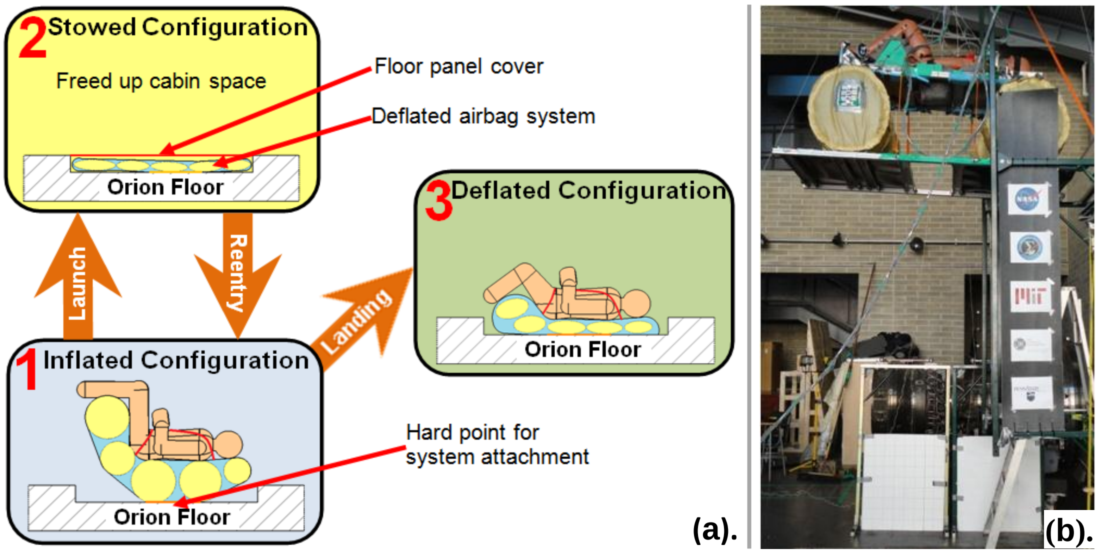

Figure 2. Orion crew exploration vehicle (CEV) capsule personal airbag (a). Concept-of-Operations (Con-Ops) [5] (b). Test Configuration [5].

A summary of the relevant findings are listed below:

1. Students are motivated to solve real and challenging problems
2. Students prefer to work in teams and to collaborate to solve challenging problems
3. Subject matter experts (SMEs) expend little effort yet afford tremendous leverage/impact on the quality of concepts/solutions
4. Senior students are ideal mentors for immediate junior counterparts
5. Students from multiple universities can effectively collaborate and solve a common challenge
6. Students enjoyed the creativity and innovation lessons, especially those on Biologically Inspired Design (BID) and TRIZ
7. Some of the students wanted more time during the prototyping and testing phases
8. Novel and effective **solutions to critical and heretofore unsolvable problems can result [5]** using very small collaborative teams of students from multiple universities
9. Several capstone design ideas related to the challenge were also investigated by student teams at Penn State; one of those teams won top prize out of 70 entrants!
10. The Wiki was a very useful tool for immediate collaboration for the teams for the one-week workshop

Digging and Drilling on the Surface of the Moon (NYU-Poly – 2009)

In the summer of 2009, an interdepartmental/interdisciplinary design, 3-credit course was offered at the Polytechnic Institute of NYU (NYU Poly) entitled: "Innovative Conceptual Engineering Design." The problem/challenge selected for this course was the design of innovative methods for "Digging and/or Drilling on the Surface of the Moon." The course was offered through four traditional departments at NYU-Poly: Mechanical and Aerospace, Civil, Computer Science and Engineering; and Electrical Engineering. The class totaled 30 students with 19 undergraduates from one of the four departments from NYU-Poly and one CS undergraduate from Carnegie

Mellon; one management of technology graduate student from NYU-Poly and 10 high-school students from either Brooklyn Tech or Archbishop Molloy (two NY high schools).

A summary of the relevant findings are listed below:
1. Many of the results mirrored the first seven findings of the preceding section.
2. It was possible to mix undergraduates and high-school students effectively. In fact, it proved to have a synergistic effect on performance.
3. Students preferred the more collaborative nature across individuals and teams as opposed to a pure competitive environment
4. Students prefer hands-on-learning (HOL) activities
5. The program was able to connect several students with internships at high-tech companies
6. The program inspired entries into the NASA Lunabotics competition 2 years in a row, with a "Most Creative Design" award in 2011.
7. Senior students are excellent mentors for more junior students (near peer-to-peer mentorship)
8. There were several very interesting design ideas that were inspired by biological systems (BID)
9. Several students who had previously not considered engineering as a major course of study changed their minds, one selected NYU-Poly for an engineering degree
10. While Blackboard provided a mechanism for homework submission; grading; and many of the necessary tools for collaboration; the students found it cumbersome to use

Design of a Spacesuit for Mars (NYU-Poly – 2010)

We selected 44 students from 31 different high schools in the NY/NJ metropolitan areas for our next challenge: "Design of a Spacesuit for Mars." Classes contained lectures by subject matter experts (SMEs) from NASA, industry and academia, similar to previous classes, interspersed with videos, hardware demonstrations and a field trip to MIT where the students had lectures and witnessed lab experiments by faculty and students doing research in novel spacesuit design.

A summary of the relevant findings are listed below:
1. Many of the results mirrored the findings of previous sections.
2. While the students liked the myPort80 (a virtual platform based on the IntroNetworks software) it was still found to be lacking and many student teams chose other methods for communication and collaboration (e.g., Facebook, AIM, Google, email, etc.).
3. It was found that the virtual platform information was very useful in identifying the health of the teams (high-performing/functioning teams versus ones that needed assistance and/or intervention) and individual team members. It is also possible to differentiate individual performance from the overall team's performance.

Design of an Autonomous Vehicle to Explore Lava Tubes on Mars (Stevens Institute – 2011)

The summer 2011 program elicited the interest of the US Air Force (Tech Edge Program at the Wright Brothers Institute) and five universities. A university/government Cohort Group was used to select a challenge to pose as part of the summer challenge. The *"Epic"* challenge selected was one proposed by Dr.Rob Ambrose, Division Chief of NASA JSC's Automation, Robotics, and Simulation Division and agreed upon by our University "Cohort Group". This group was comprised of a team of faculty points of contact (POC) and graduate students from each of the five collaborating universities: Stevens Institute, Texas A&M, MIT, Penn State and Wright State; our Air Force Partners at Wright Patterson AFB, and the Wright Brothers Institute. This version of the ICED program experimented with three new implementations: (1) capturing online learning lectures of SMEs from NASA, industry and academia on the iQ4 virtual platform for use by the students; (2) an organizational framework described in a later section; and (3) a different Hub university, Stevens Institute.

A summary of the relevant findings are listed below:

1. Many of the results mirrored the findings of previous sections.
2. The online learning component proved to be very useful in not only allowing students to review material but to also scale the program and reduce costs
3. While the students liked the myPort80 (a virtual platform based on the IntroNetworks software used in the previous offering), there was much more collaboration using iQ4 with capabilities to blog, chat, create groups and subgroups; post ideas/concepts, etc.
4.

Sustaining Humans on Mars – Habitat Design (MIT – 2012)

The latest ICED challenge was kicked off the summer of 2012 with two separate one-week sessions at MIT. The first session was called the ICED 2012 *Innovation Bootcamp* and focused on the training of high-school Teacher Coaches (TCs) and graduate and undergraduate student team members from MIT. During this first session the participants were instructed in the ICED methodology and were immersed in the *"Epic"* challenge by a series of live and distance learning lectures by SMEs from NASA, industry (Cambrian Innovation), and academia (MIT, University of Houston, University of New Hampshire, and Tufts) in areas of Mars Habitation, Space Radiation, and Environmental Control and Life Support Systems (ECLSS) (Table 2). During the *Innovation Bootcamp*, the teacher-student teams were tasked to create Khan-style [11] videos of some of the ideas generated, in addition to concept maps of the concepts taught, and their relationships [23]. The collection of all videos would be used together with hands-on-learning exercises by the participants to create online learning modules and other online resources [11-13]. These are intended for future formal and informal courses to be created by the TCs from each of the Hub high schools selected to participate in this pilot program to be used for the upcoming school year. The MIT student mentors were tasked with the creation of the lessons for the second, one-week session called: "*The Creative Concepts Collaboratory (CCC)*." The MIT program was based on an organizational framework and operational structure and network of University Hubs, local High School Hubs, and satellite high-school(s)/middle-school(s) (see section entitled: ICED Organizational Framework). A total of 40 high-school students representing high-school Hubs from NJ, NY, and MA were selected to participate in the second one-week session.

Table 2. Course schedule for ICED 2012 Innovation *Bootcamp* at MIT.

Time	Sun 6/24	Mon 6/25	Tue 6/26	Wed 6/27	Thu 6/28	Fri 6/29
8am		ICED Methodology	GCRs & SPEs Overview	ECLSS Overview	Env. Monitoring	Video Recording
				Historical ECLSS Overview: Gemini – Shuttle		
9am		Return to Flight	Rad Shielding		Fire Safety	August Workshop Planning Session
					Bio Processes	
10am		Mars Architectures	Human Rad Protection	ECLSS Arch Considerations	Stupid Ideas	
11am		Space Radiation Overview	Radiation Biology	Air Revitalization	Video Recording	Walter Lewin Lec
12pm		Lunch	Lunch	Lunch	Lunch	Lunch
1pm		Minimum Functional Hab	Electronics & Radiation	Water Recovery	Video Recording Session	Final Team Presentat-ions
2pm		Intro to Sys Engineering	Rad Trades	Waste Management		
			Rad Demo		Design of Experiments	
3pm	Welcome, Week Overview & Objectives	Func Decomp	Rad Modeling	Nature as Innovator: Biologically Inspired Design		
		Innovation & Creativity	Space Env. On Humans		Microbial Fuel Cells & DOE	Break
4pm						Program Wrap Up
	Icebreaker - Creativity Team Activity	Khan Videos	Research Techniques			
5pm		Break		Break	Break	
		Dinner & Break	Dinner & Break	Dinner & Break	Dinner & Break	
6pm	Welcome Reception					
7pm						
	NIAC Study: Rad Shielding	Video Storyboarding Session	Video Storyboarding Session	Video Production Session	Video Recording Session	
8pm						
	Mars Movie Night					
9pm						

ICED Organizational Framework

The program relies on a complex, multidisciplinary problem or "*Epic*" challenge which has the vested interest of the program sponsors (NASA and MIT in this case). The organizational structure/framework is shown in Figure 3. A "Cohort Group" of 5-7 points of contact (POCs), one for each of the university "Hubs", was selected to help guide the selection of the "*Epic* Challenges" together with NASA SMEs and form the top-level mentorship platform from which the flow of curricula, age-appropriate learning modules, mentors, etc. would emanate. The Executive Advisory Board consists of key educators (from middle, high-school, and university levels), technical experts, virtual platform builders/engineers, and administrators and assists in the development and oversight of the program.

The *"Epic"* Challenges flow to the university Hubs, each consisting of a network of graduate students addressing each individual challenge. Each challenge would then form a separate network or virtual community. These individual problem-based networks or communities will grow and shrink in size according to the needs of the particular challenge using a "flexible critical mass" approach [24]. The virtual platform will be critical in linking students together, enabling effective communication and collaboration, and for providing an environment which encourages innovation, rapid learning and critical thinking. The MIT pilot program selected four high schools in Massachusetts, three in New Jersey and one in Texas and, hence, had one TC representing each school during this session.

Integration of Undergraduate and Graduate Student Mentors

The decision to have MIT student mentors play a lead role in the development of the lectures and activities for the second phase of the program was instrumental in its overwhelming success. This was achieved by providing the correct level and mix of lectures, creativity exercises, hands-on-learning (HOL) experiences and prototyping and model building. Peer mentorship, although only briefly utilized in previous programs, was an integral part of the second phase and is recognized as an important element of the "Continuum of Mentorship" (yellow downward pointing arrow in figure 3) – the heart of the educational outreach component of the program. The creativity of the younger students flows up and is acknowledged by slightly senior peers while the analytical rigor and modeling skills needed flows down to junior participants.

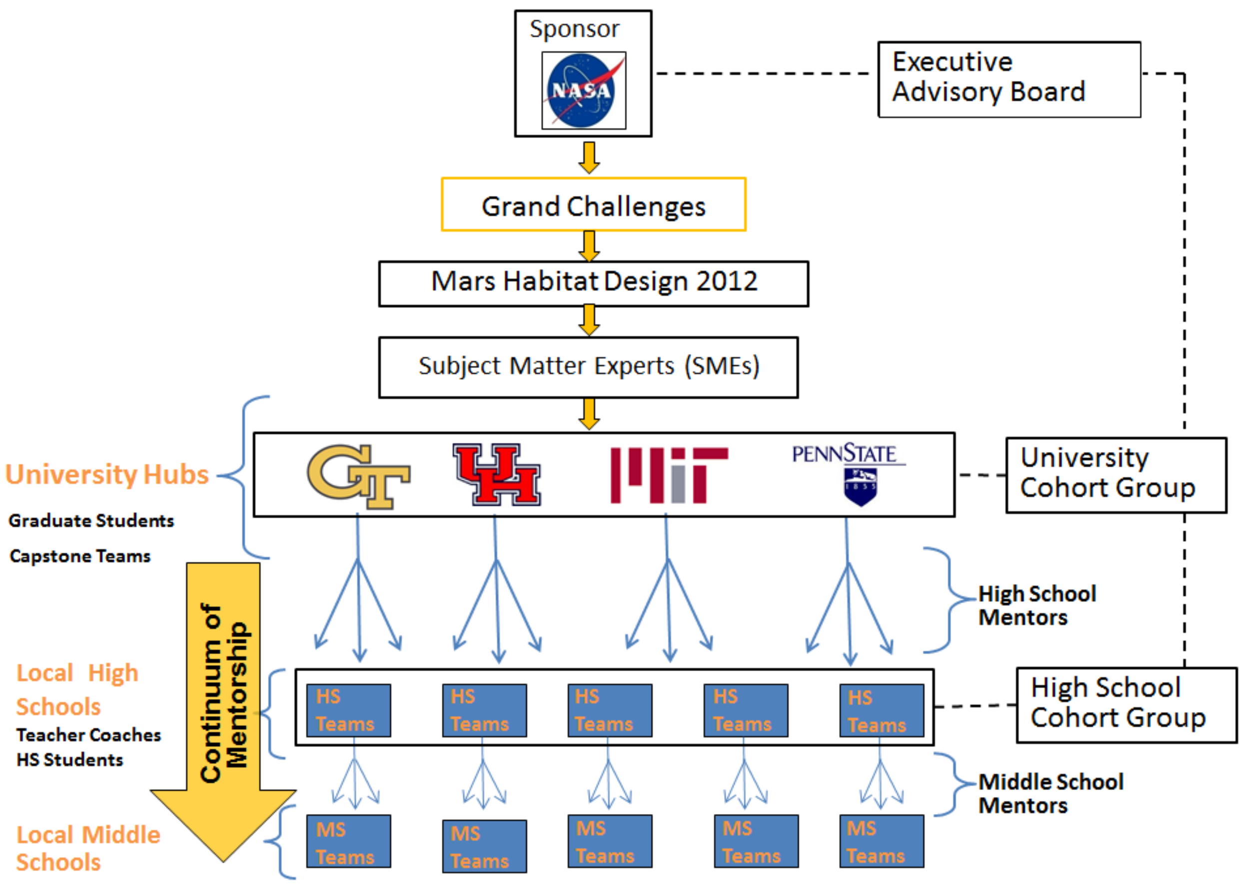

Figure 3. Innovative Conceptual Engineering Design (ICED) Organizational Framework and Operational Structure.

The use of functional decomposition [26] together with concept mapping [23] to help decompose the complex, multidisciplinary challenge into bite-sized and related knowledge concepts and elements of study also proved to be a very useful tool which was later implemented by TCs in the follow-on, school-year programs. The use of concept maps proved very helpful in relating the undergraduate/graduate concepts to age-appropriate science and engineering elements of the high-school programs. Figures 4 and 5 illustrate how the functional decomposition of the Mars Habitat challenge by SMEs and Graduate students using Object Process Modeling (OPM) [25, 26] can be used together with concept mapping (Figure 6) [23] to relate undergraduate/graduate concepts to age-appropriate science and engineering elements of high-school programs. These can in turn be related to online learning tools like the Khan Academy [11] and FlexBooks [12]. The follow-on programs at the eight Hub high-schools had student membership of over 140 students.

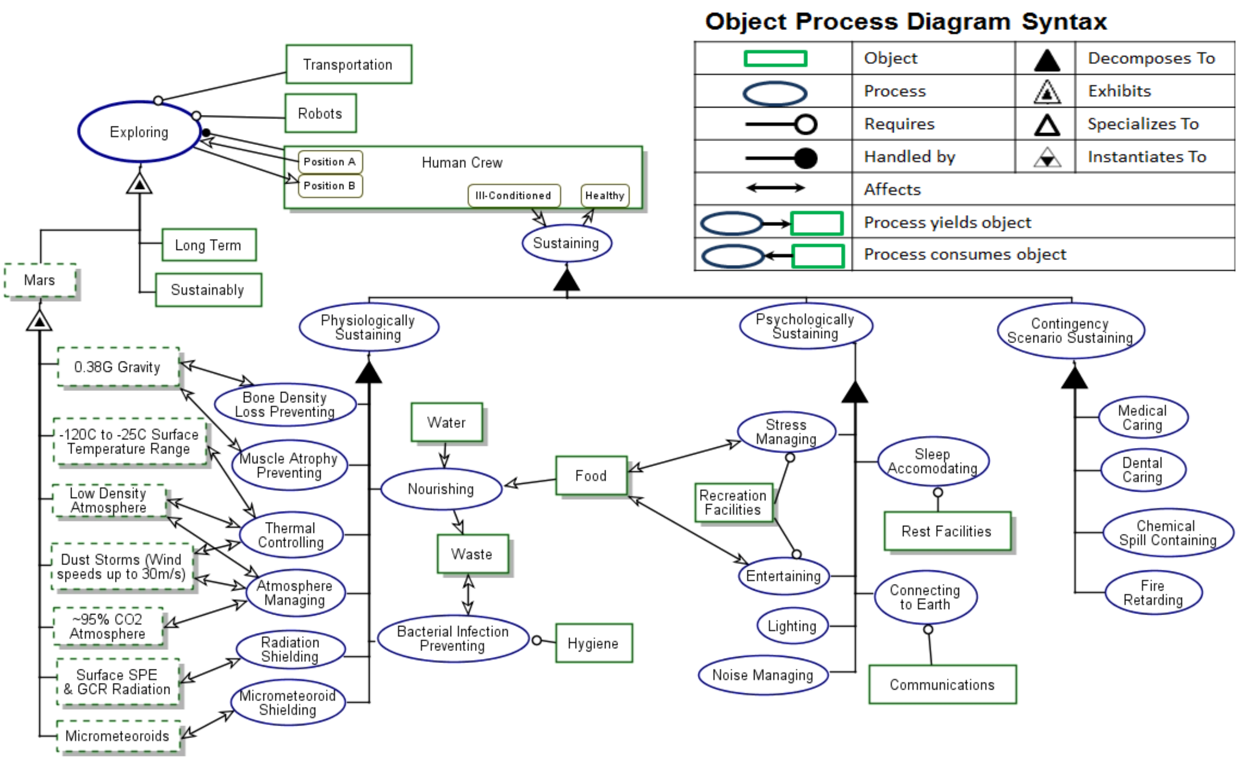

Figure 4. Functional Decomposition of Sustaining Humans on Mars – Habitat Design Challenge using Object Process Modeling (OPM) [26]

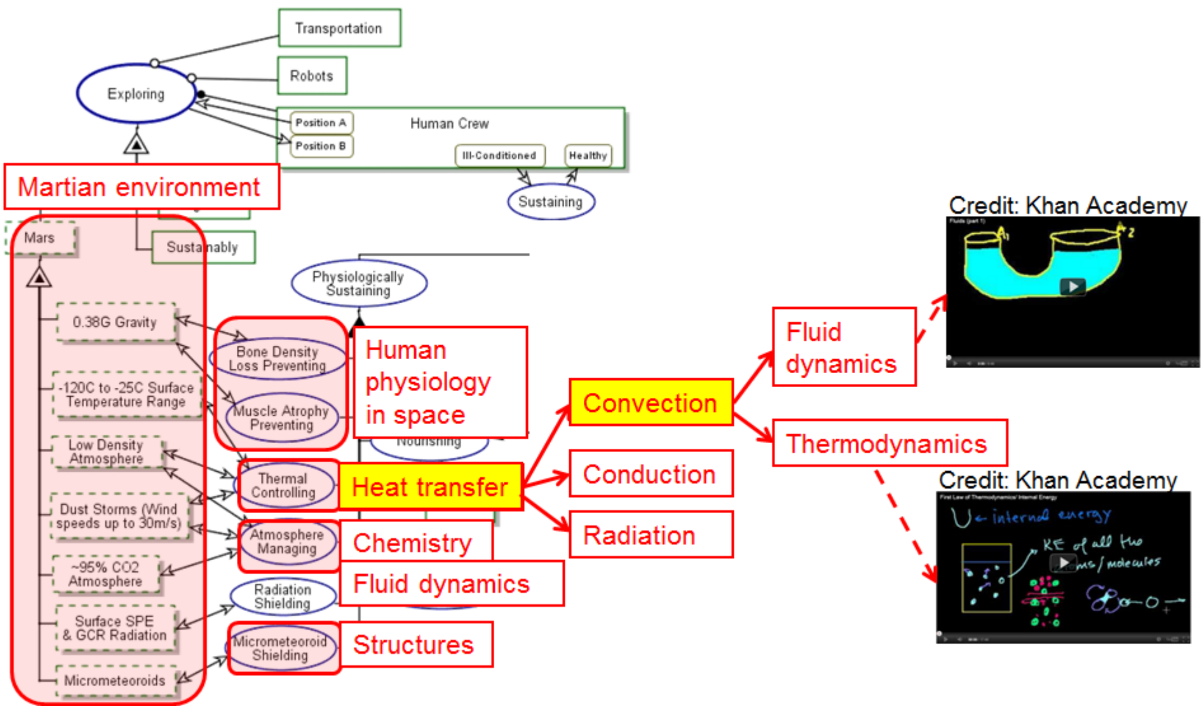

Figure 5. Relationship of challenge disciplines/domains to related high school subjects and online learning tools such as the Khan Academy [11]

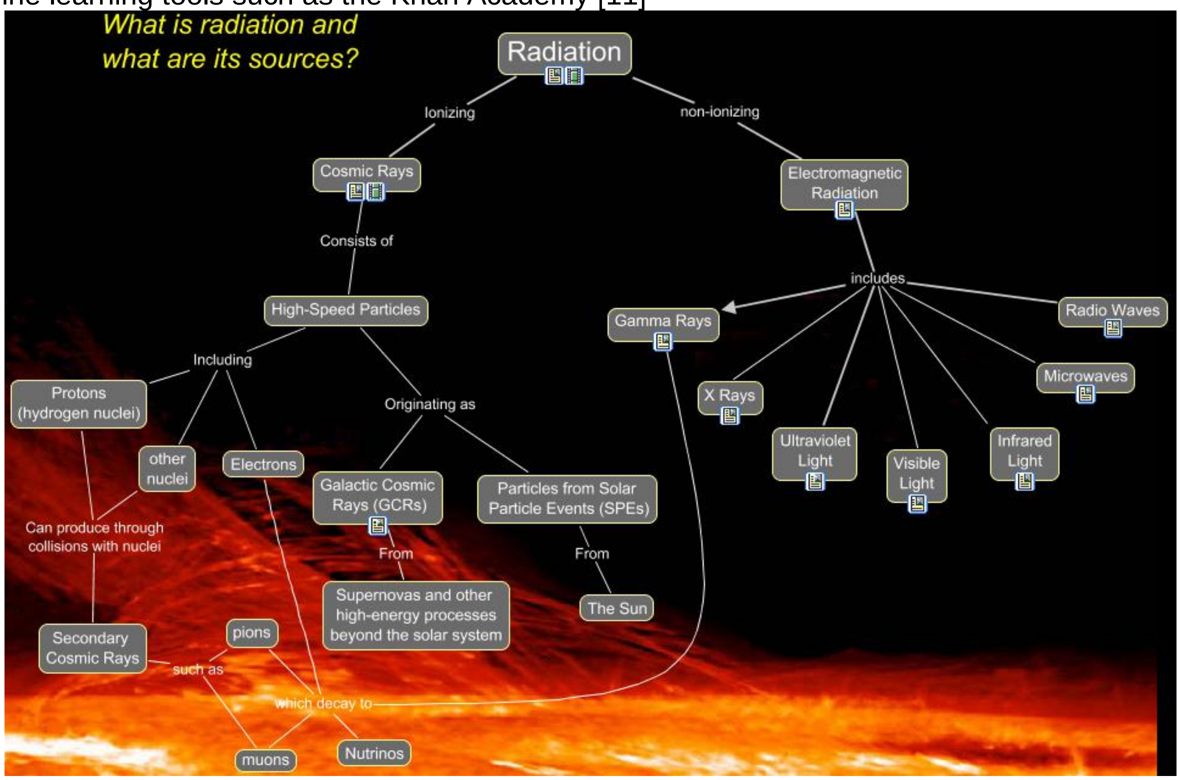

Figure 6. Concept Maps (Cmaps [23]) are used to relate age-appropriate knowledge and links to complex problem solution and advanced learning concepts.

A summary of the relevant findings are listed below:

1. Many of the results mirrored the findings of the previous sections.
2. Use of undergraduate/graduate students as mentors and course creators proved very effective
3. Teacher Coaches (TCs) from Hub high schools have created and shared lesson plans focused on the selected challenge
4. SMEs from NASA and National Labs around the country are providing resources for HOL experiments and activities
5. Follow-on high-school programs being developed include: formal elective semester and full-year programs as well as informal, after school programs
6. Concept mapping is proving to be a very powerful tool to link new knowledge with prior, appropriate knowledge and thus result in meaningful learning: use of Cmap software [24] is expanding throughout the teams
7. Online capture of all learning elements have been made available for public access
8. Videoconferencing is being used effectively to persist in the motivational and educational success of the program. SMEs from NASA voluntarily held videoconferences with students and teachers.
9. Use of Google Drive products & iQ4:
   a. Google products are being used by some of the high-schools to post findings (e.g., Khan-style videos, concept maps, student presentations, etc.)
   b. iQ4 is still in the process of evaluation but was not used formally

CONCLUDING REMARKS

The Innovative Conceptual Engineering Design (ICED) methodology is proposed as a means to infuse creative problem solving and innovation within a team-oriented, problem-based learning program such as CDIO to inspire excellence in STEM education and achievement. Experience with ICED has been collected over the past five years (2008 – 2012) with teams made up of: practicing engineers, tenured and associate faculty, graduate and undergraduate students, and high school students. Results presented indicate that innovative solutions to complex, multidisciplinary problems which have confounded NASA for over 50 years, such as the safe land landing of a space capsule, could be solved by the collaboration of students from multiple universities. In addition, entire courses of study revolving around similar, *"Epic"* challenges have been created which inspired student participation in STEM-related problem solving – a key step in bridging the gap between high school and university programs. Other observations include: 1) students are highly motivated to solve real, relevant problems, 2) students prefer to work collaboratively, 3) students enjoy creatively expressing novel ideas which have never been considered, 4) senior students prove to be excellent mentors for their slightly junior counterparts, 5) resources (people, test facilities, laboratory equipment, etc.) from across the country can be shared with very little impact and/or cost to existing programs, 6) design challenges can very easily transition to formal and informal educational experiences in multiple areas of engineering, science, and math, 7) students enjoy hands-on-learning exercises and experiences, and 8) a mixture of live and virtual (online tools: lectures, Skype, video, audio, data, documents, etc.) learning methods can be incorporated to reduce costs and successfully scale programs.

Future work includes the development of a user-friendly, collaborative virtual platform that: 1) links online learning tools with student teams 2) facilitates student collaboration; 3) assists curriculum development by teachers and relates courses to core standards via a Lesson Planning Center (LPC), and 3) develops analytics to measure creativity, teamwork, information flow, networks, and performance of individuals and teams.

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