AC 2011-2360: INSTRUCT INTEGRATING NASA SCIENCE, TECHNOLOGY, AND RESEARCH IN UNDERGRADUATE CURRICULUM AND TRAINING

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INSTRUCT – Integrating NASA Science, Technology, and Research in Undergraduate Curriculum and Training

Abstract

A key factor in increasing the number of underrepresented minorities in science, technology, engineering, and mathematics (STEM) disciplines is through the stimulation of the student's interests in these disciplines. Several underrepresented minorities at North Carolina A&T State University are first generation college students in their family, and could fail to understand the applicability of STEM disciplines. In addition, many students find the basic STEM discipline courses to be hard, boring, and do not realize the practical applications of the concepts and techniques that they are learning in their STEM classes. Agencies such as National Aerospace and Space Administration (NASA) require and apply several of the basic STEM content and require an educated workforce trained in the STEM disciplines. In addition, these and other agencies have a mission to increase the number of underrepresented minorities and women in STEM areas. The INSTRUCT project at North Carolina A&T State University focuses on integrating NASA science, technology and research content into the undergraduate curriculum. Our INSTRUCT project strives to significantly enhance and stimulate undergraduate learning in the areas of science, technology, engineering and mathematics by utilizing the relevant STEM content from NASA, sponsored research and education programs from NASA, in conjunction with our university faculty expertise.

This paper discusses the INSTRUCT program, current development and integration of the NASA STEM content into the existing course curriculum; teaching and delivery of the enhanced course content, evaluation, outcome and impact on the student stimulation of the learning, understanding, engagement and success. The success and impact of the project includes formative and summative evaluation of the project goals, as well as long term tracking of selected students on the influence of the INSTRUCT program in motivating them to pursue STEM based higher education and careers. This potentially could lead to a long term societal impact by increasing the number of underrepresented minorities in STEM workforce areas.

Key Words: STEM education, minority education and training, undergraduate education, STEM curriculum enhancement

Introduction

Student stimulation and motivation is a key factor in increasing the number of underrepresented minorities in science, technology, engineering, and mathematics (STEM) disciplines. Many students find the basic STEM discipline courses to be hard, boring, as they do not realize the practical applications of the concepts and techniques that they are learning in their STEM classes. Agencies such as National Aerospace and Space Administration (NASA) require and apply several of the basic STEM content and require an educated workforce trained in the STEM disciplines. In addition, these and other agencies have a mission to increase the number of underrepresented minorities and women in STEM areas. The INSTRUCT project at North Carolina A&T State University focuses on integrating NASA science, technology and research content into the undergraduate curriculum. Our INSTRUCT project strives to significantly enhance and stimulate undergraduate learning in the areas of science, technology, engineering and mathematics by utilizing the relevant STEM content from NASA, sponsored research and education programs from NASA, in conjunction with our university faculty expertise.

The mission of NASA and its four directorates (Aeronautics, Exploration Systems, Science, and Space Operations) requires STEM content that includes the bio-chemical sciences, physical sciences (earth and atmospheric sciences), engineering and mathematics. The INSTRUCT program at our North Carolina A&T State University is developing, implementing, evaluating and disseminating innovative pedagogical concepts for integrating the associated NASA STEM content into the STEM undergraduate courses at our university. The courses that have been chosen for inclusion are large enrollment core courses that are critical to undergraduate student success. This provides excellent opportunities to incorporate NASA content towards motivating the student engagement and success. Specific undergraduate courses in astronomy, mathematics, biology, chemistry and mechanical engineering are currently targeted.

This paper discusses the INSTRUCT program and its objectives, educational content development and integration of the NASA STEM content into the existing course curriculum during the first year of the program; teaching and delivery of the enhanced course content, evaluation, and its impact on the student stimulation of the learning, understanding, engagement and success

INSTRUCT program

The NASA INSTRUCT program at North Carolina A&T State University focuses on integrating NASA science, technology and research content into the undergraduate curriculum. Our INSTRUCT program strives to significantly enhance and stimulate undergraduate learning in the areas of science, technology, engineering and mathematics by utilizing the relevant STEM content from NASA, sponsored research and education programs from NASA, in conjunction with our university faculty expertise.

Goals and Objectives

The objectives of the INSTRUCT project is to integrate NASA content into STEM undergraduate courses with a primary emphasis on stimulating interest in STEM disciplines towards increasing the number of under-represented minorities and women in these areas. The specific goals of the INSTRUCT program are to:

1. Increase and stimulate the participation of underrepresented students in STEM disciplines
2. Retain underrepresented students in STEM disciplines
3. Foster the integration of NASA content into undergraduate education and training
4. Promote the career preparedness of undergraduates by integrating NASA content based learning techniques throughout the STEM curricula
5. Increase the number of students going to graduate school in NASA relevant technology areas
6. Increase student and faculty exposure to NASA research and technologies and their relevance to undergraduate academic courses

Project Innovations

The pedagogical and effectiveness of stimulating the interest in STEM areas is achieved through the following innovations that form the guiding principles of the module development that is envisioned in the INSTRUCT project.

- All modules were developed based upon STEM education research and best practices
- Interdisciplinary team approach was utilized that allowed NASA content to be incorporated into biology, atmospheric science, and engineering courses
- Module booklets are being developed such that these will be published for wide dissemination
- Use of modern educational technologies (virtual self-study modules and exercises, web based tutorials, other techniques such as Magic Planet presentations) were used to communicate NASA research data

The vision and the pedagogical innovations strive towards increasing the student interest and under-represented minorities in the STEM areas and to enhance their opportunities for STEM related careers. The first year of the project efforts primarily focused on the module content development and implementation. Details of these developments and preliminary implementation are discussed next.

INSTRUCT Module Development

The first year of the INSTRUCT project emphasized integrating NASA science, technology and research into specific undergraduate courses in the areas of Physical Sciences (with a focus on

earth and atmospheric sciences), Biology, Mathematics, Chemistry and Engineering. In these five areas, we developed six modules and pilot evaluated four such modules in the associated undergraduate courses into the curriculum impacting over 300 undergraduate students. The subject areas of these modules include in the areas of earth and atmospheric science, biology and mathematics, Chemistry, Physics and Engineering. The undergraduate courses that are impacted by these modules during the first year of the INSTRUCT are presented Table 1.

Module Subject	**Course Name**	**Course Number**	**Number of students impacted**
Mathematics	Calculus II	Math132.005	40
		Math132.008	40
	Introduction to Differential Equation	Math 431.005	40
Earth and Atmospheric Sciences Module	Weather & Climate Studies	UNST 234.001 UNST 234.005 (online)	25 25
Biology	Freshman Biology II	BIOL 102.001	29
Chemistry	Biotechniques in Biochemistry	Chem 451.001	27 (module partially implemented)
Materials	Fundamentals Materials Science	MEEN360.001	31 (module partially implemented)
	Modern Engineering Materials	MEEN460.001	26 (module partially implemented)

Table 1: Undergraduate courses and curriculum impacted by INSTRUCT project

The details of the specific individual modules, their development and associated implementation are discussed next.

Earth and Atmospheric Sciences Module

This module was developed under the direction of a faculty member with a background in Chemical Engineering, Energy and Environmental Systems. The relevance of the module to the NASA research needs and the contents of the developed module are discussed next.

The changes of the earth and its effect on the life on earth is a fundamental area of interest for NASA with focus areas that include the atmospheric composition, weather, carbon cycle and ecosystems, water and energy cycles, climate variability and change. Future trained graduates in

these areas are critical for NASA's mission, and, thus, it is important to induce student interest in these areas. This INSTRUCT module focuses on integrating NASA STEM content into an introductory undergraduate course offered through the energy and environmental cluster of the University Studies (UNST) program and an introductory astronomy course offered through the physics department. UNST is the interdisciplinary general education curriculum at our university.

In this specific module, the integration of NASA content is achieved by incorporation of inquiry-based learning activities utilizing NASA data (Schimmel et al., 2005; Hilger et al., 2007). The introductory astronomy course (Astronomy 101) integrated the NASA content from Cool Cosmos, and the topic areas of light and tools of the astronomer are inter-weaved throughout the semester.

The primary NASA research and education resources that are being utilized for this module development are from NASA's Earth Observing System (EOS). Parts of the following resources were utilized in UNST 234:

1) NASA satellite data at the USGS Land Processes Data Active Archive Center (LP DAAC)
2) NASA Digital Learning Network (Our Planet Earth, Solar Energy, Mission Geography, NASA Careers)
3) Earth Audio Podcasts (The Space Hunt is On for Carbon Dioxide, Tall Oceans and Global Warming, A Walk in the Clouds with a NASA Satellite)
4) Earth Video Podcasts (Oceans of Climate Change, 25 Years of Landsat 5, Taurus is OCO's Ride to Space, Orbiting Carbon Observatory)
5) Interactive Features (Eyes on the Earth 3D, Frozen: Cold Matters)
6) Central Operation of Resources for Educators (CloudSat: Revealing the Inner Secrets of Clouds, NASA SCience Files: The Case of the Phenomenal Weather, NASA SCience Files: The Case of the Mysterious Red Light, Sea Winds: Catch the Wind the WuikSCAT Story, Space Weather: Exploring Sun-Earth Connections, Meteorology: An Educator's Resource for Inquiry-Based Learning, NASA CONNECT: The "A" Train Express, Careers, Geography)

The NASA content module was implemented into the teaching of the newly developed online version of Weather & Climate Studies (UNST 234) during the second summer session of 2010, Because of the quick pace of a summer session course (one month long), the aerosol module was utilized only as an extra credit assignment. Feedback from the students clearly indicated a positive response for the module and its effectiveness in the understanding and related to the course content.

The details of the biology module, the relevance to the NASA needs and the current developments are discussed next. The biology module is an effort of two biology faculty members.

Biology Module

NASA recognizes that for long-duration missions in space, such as living permanently on the moon or Mars, a Bio-regenerative Life Support System (BLSS) approach will be needed to sustain humans. Plants generate food and oxygen; remove carbon dioxide, while at the same time purifying waste water into clean water. NASA initiated the Controlled Ecological Life Support System (CELSS) Program to continue research on bio-regenerative life support, with much of the effort focused on controlled environment production of higher plants (Bugbee, 1999). These studies were conducted at several universities and NASA field centers under the Advanced Life Support (ALS) Program (Galston, 1992). Since longer missions dictate using regenerative life support approaches, a BLSS represents an enabling technology for human survival on a Lunar or Mars surface habitat. BLSS commodities include provision and recycling of O_2, H_2O, and food through the process of photosynthesis (Corey 1992). The operation of a BLSS presents an interdisciplinary STEM learning model to predict the output of these life support commodities.

Human survival over long periods within the harsh outer space environment is a sobering concept and provides ample opportunity to engage and stimulate students with fundamental biological concepts. Therefore, we will employ this space exploration concept to compare NASA regenerative life support (closed-loop) vs. re-supply (open-loop) mission requirements. This BLSS teaching module will cohesively connect material toward constructing an autonomous space colony.

The biology module incorporates NASA manned exploration mission issues that instigate cross-cutting themes and discussions in and out of the biology classroom. The costs and reliabilities for different life support options (open vs. closed-loop) can be evaluated by students for a given space mission. This approach will help instructors better connect biological system scales from atoms to ecosystems. Students will gain better insight into primary metabolism, photosynthesis, flow of energy, thermodynamics, and ecological recycling through integrated discussion at class meetings. The biological sciences are becoming increasingly more dependent on concepts and techniques from other STEM disciplines. Hence, the space exploration platform also enhances interdisciplinary student learning in current and subsequent STEM courses. By encouraging collaborative group work, the proposed BLSS teaching module will serve as a model to other faculty for sustaining a forward-thinking introductory biology classroom.

As a part of this module development, Bioregenerative Life Support Compartment Models based on existing Advanced Life Support Designs from the NASA Life Sciences Data Archives-LSDAS. (http://lsda.jsc.nasa.gov) was developed. The Advanced Life Support System (ALSS) concept is that of a human life support system, supplying food, water, and oxygen can operate indefinitely in space without resupply from Earth. This system is open with respect to energy but closed with respect to mass. This means regenerative or recycling technologies must be used. This was developed employing SimBiology®, an integrated environment for modeling biological processes, and analyzing the models with simulation and experimental data. SimBiology® is a toolbox add-on to MATLAB®, and hence is able to use other tools provided by MATLAB®. SimBiology® provides a complete modeling environment that includes both a graphical front end and a proven mathematical engine. SimBiology® features a drag-and-drop interface, so that students who are non-programmers can create, edit, and view models of pathways. The developed module would thus allow students to simulate the modeled reactions with deterministic and stochastic simulation solvers, and then analyze the resulting data in SimBiology or perform custom analysis with MATLAB®.

The details of the module development in mathematics are discussed next. The mathematical modules targeted the undergraduate mathematics courses in calculus and differential equations. Both mathematical modules were developed under the direction of the mathematics faculty who teach these courses.

Calculus Module

Mathematics and in particular calculus are integral requirement of STEM education. At our university, all students studying engineering and science disciplines are required to take calculus. Although the content of calculus is important for student's leaning in other courses, many students view calculus as hard and not useful. They do not relate the relevance of calculus to the key science and technology applications. The student’s perception is that they now have many modern computational tools to help them get by without a solid understanding of calculus.

Learners of all ages are more motivated when they can see the useful applications of what they are learning. The calculus module focused on using selected relevant topics in NASA’s mission to enhance the quality of the teaching of calculus. The need for scientific computations involving the application of calculus in NASA’s space explorations will be emphasized in such module. This was achieved in a systematic manner with development of a module incorporating NASA activities and content into the teaching of calculus. For example, students will be introduced to information about the shape of various space crafts and shown that the volumes of such spacecrafts can be computed by using the disk and shell methods in calculus. Other issues such as computing light reflection on different shapes of mirrors will be included in the modules.

A module with the following characteristics was developed to be used in the Calculus II (Math 132) course.

The module involves calculating the volume of the volume of spacecraft Orion, the mathematics involved the use of following mathematical concepts.

- write down linear function if given two points;
- write down equation of circles if given three points (solve systems of equations)
- the disk method in volume;
- Integration techniques including trigonometric substitution.

This module shows that mathematics knowledge and skills are important in NASA's exploration in outer space and research. Students need to use the Disk method (just introduced in Calculus II, course Math132) to find the volume of crew module—Orion. Students also need to review basic algebra skills (such as solving system of two or three equations, using quadratic formula) and they will need to use more integration techniques to evaluate integrals to find the volume.

The details of the second mathematics module are presented next.

An Exploration of Hurricane Paths using Differential Equations

In this module, The NASA's data is used to show the weather phenomenon (the hurricane paths, animation), after which the underline equations are introduced to the students. For the simple differential equations, the students can analytically solve and sketch the solutions of these equations. The questions are given as words problems. The students need to figure out the equation and solve it then explain it. A GUI (graphical user interface, built on MATLAB) for the equations will also be available. In this module, the students can explore by themselves the various hurricane paths. Motivated (interested) students can do a project to further explore the numerical prediction for the hurricane paths and write their own MATLAB code for some simple numerical computation. In this module, the differential equations themselves are not so difficult. The difficult part is the explanation/interpretation of the equations. Our weather system is dynamic. Dynamic systems are differential equations, roughly speaking, in a sense. Even though there are tons of or millions of factors in the weather system, for one dynamic phenomenon, we can always identify couple of factors that play the main role. With only a few factors, there is the simplified system of differential equations that can be used to explain the complicated weather phenomenon and the present module ties the weather phenomena to the governing differential equations studied during the course.

The relevance and details of the modules in materials engineering and chemistry are discussed next.

Materials Engineering Module

Current and future space initiatives require lightweight material systems that can perform as load-carrying structures (structural skin and walls of spaceships, rovers, planet outposts, and space stations) in the operating conditions of space environments. The processing and manufacturing of such light weight material systems consisting of polymer composites (fiber-matrix composites with new material systems for nano-level materials integrated to improve thermo-physical properties, ceramic matrix systems for high temperature operating conditions, etc.) are important technological barriers that need to be addressed for the successful application of these new material systems.

Carbon based fiber composites with epoxy resin systems are regularly used in several aerospace applications including high speed aircraft systems. These fiber composites are lightweight, and they can be tailored to meet specific property requirements for advanced engineering applications. In addition, liquid composite molding processing techniques provide a capability for fabrication into complex, structural load-bearing systems for space vehicles, rovers, and human habitats and are of importance to NASA mission needs. Over the years significant technology and research developments have been accomplished on the mechanics, behavior and processing of these composite material systems resulting in a vast amount of NASA research content in these areas. The integration of these advanced composite material concepts into the curriculum content of the traditional materials and manufacturing undergraduate courses will be the focus of these modules.

Undergraduate courses at our university in materials sciences (Materials Science; MEEN Modern Engineering Materials; Manufacturing Processes) are targeted for integration of NASA research content on polymer composites, metal matrix composites, high temperature ceramics composites, their processing and mechanics. The importance of these material systems for the NASA mission will be emphasized by providing the relevance of these materials to practical applications.

The details of the biochemistry module under the direction of a chemistry faculty are discussed next.

Biochemistry Module

NASA has well documented the physiological effects of human life during extended space missions. Long periods of reduced gravity have been shown to have a number of adverse physiological effects on the nutritional status of astronauts during a space flight (Vodovotz, 2000; Tobin, 2002; Smith, 2008). Thus, many issues such as macro- and micro- nutrient

balance, energy balance, vitamin and mineral deficiencies must be considered for the safety of crew members during these missions.

Two case studies based on the effects of space flight on human health will be to supplement lectures on topics such as glucose metabolism, calcium and bone metabolism, cell signaling, and nutrition and energy balance in biochemistry courses at our university. The studies will allow students to see relationships between metabolic biochemical pathways and the serious risks posed to humans when exposed to reduced gravity conditions during a flight mission, providing relevance of their course curriculum to the practical needs and in particular the NASA mission. In addition, students will have an opportunity to develop writing, critical thinking, and analytical problem solving skills that are required for a broader interdisciplinary perspective. The case study exercises will also involve cooperative-collaborative teaching strategies to enhance the learning environment.

Evaluation and Assessment

The first year of the project focused on the development of the modules and pilot implemented in some cases. A formal evaluation on full implementation has been planned. The details of the assessment plan through internal and external evaluations are discussed next.

INSTRUCT project will involve both a formative and summative evaluation to be conducted as part of the overall evaluation of the project activities and their impact. These evaluations will be conducted by an independent evaluation agency. The purpose of the formative evaluation is to ensure that the goals of the project are being achieved and to identify any areas where improvements are needed. The formative evaluation will begin at the start of the project and will continue throughout the life of the project. The summative evaluation will formally begin once students begin participation, recognizing that the boundary between formative and summative evaluation is blurred, and will continue through the life cycle of the project. The goal of the summative evaluation is to assess the degree to which project outcomes have occurred and to identify any unexpected outcomes. Both formative and summative evaluations will be developed to pay particular attention to issues and results related to scaling and expansion of the project objectives to intra- and inter- universities.

A mixed methods approach will be used for both the formative and summative evaluations. A mixed methods approach to conducting evaluation is different from using multiple methods or a combination of methods in that data from one type of method (quantitative or qualitative) is merged, connected, and/or embedded with data from the other type of method (Creswell, 2006). The use of a mixed methods evaluation approach developed from the belief that mixing quantitative and qualitative evaluation methods frequently provides richer data sets and allows for better triangulation of data.

The evaluations will involve the comparative evaluation of the students who have had enhanced curricula and those that are not, to see if there are differences in terms of students'. The details of such evaluation will include several factors such as:

- Understanding of core course material,
- View of core course material as relevant to their learning,
- Abilities to make new or more connections between core course materials and other disciplines as a result of these components,
- Interest in STEM and/or NASA related disciplines,
- Intent to pursue more STEM and/or NASA related coursework, and
- Intent to pursue STEM and/or NASA related careers.

In the future years, the evaluation will include a means for assessing whether students' exposed to these curricular components actually did pursue more STEM and/or NASA related coursework and/or careers, as well as investigating the impact at inter- and intra- university replications. Complete outcomes and findings from the evaluations will be documented and disseminated.

Concluding Remarks

Student motivation at the undergraduate level is an important factor that influences the success and increase the number of under-represented STEM discipline. The INSTRUCT project at North Carolina A&T State University focuses on the integration of NASA content into undergraduate classes. The present paper discussed the INSTRUCT program and the details of the development of the subject modules for implementation into several undergraduate courses in STEM disciplines. The preliminary pilot implementation of some of these modules in some courses clearly showed the effectiveness of this approach. Formative and summative evaluations with a full implementation are planned, and will be presented in the future. The INSTRUCT program at our university is expected to be successful in motivating them to pursue STEM based higher education and careers. This potentially could lead to a long term societal impact by increasing the number of underrepresented minorities in STEM workforce areas.

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