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Paper Session II-C - Space Settlement Design: A Unifying Theme for Skill Development Through Scientific Inquiry

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Space Settlement Design: A Unifying Theme for Skill Development Through Scientific Inquiry

Last July we celebrated the 30^{th} anniversary of the first landing on the moon. Comparable scientific and technological advances will drive the 21st Century. Are our children ready? Recent studies by the Third International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP) report that U.S. students' performance is unacceptable. International ranking across 17 nations shows eighth grade students in the United Sates perform poorly in both science and mathematics. In a comparison of achievement in scientific inquiry, the U.S. ranks thirteenth among the 38 nations participating in the study. This decline is a serious national problem. Steps must be taken to correct these inadequacies if we are to prepare our nation's youth for the new millennium. In 1969 space sciences provided the needed boost for science and mathematics education. Space sciences can again provide a focus for the enrichment of education in the 21^{st} Century. Space Settlement Design: A Unifying Theme for Skill Development Through Scientific Inquiry is offered as a model for the enhancement of science and mathematics education in the 21^{st} Century.

The proposed model, initiated as a pilot middle school to high school transition program in 1997, is a three-week, half-day Summer Institute utilizing "hands-on" scientific inquiry as the springboard for skills development. Two Institutes are offered each summer. Modeled after the Jet Propulsion Lab's (JPL) *Spaceset* and NASA's *International Space Settlement Design* competitions, Institute participants are divided into groups, or "corporations," and engage in a "real-world" problem-solving scenario of space settlement design. Participants receive ½ high school science credit. Completion of the Institute is encouraged by allowing students to change from a graded to a pass/fail status on the final day of the Institute. Over the last four years Institute enrollment has increased dramatically, due in large part to the popularity of its space settlement design theme. The 2000 Summer Institute had 135 participants. The 2001 Institute is expected to enroll over 160 incoming ninth graders. Tracking of Institute "graduates" has shown a significant increase in student success in both science and other academic subjects when compared to the control group of non-Institute students.

The Institute enriches the traditional high school science and math curricula by its unique cross-disciplinary format and by addressing Earth/Space Sciences. Earth/Space Sciences are not offered by most high schools, an omission that leaves tomorrow's citizens deficient in their knowledge of space and space exploration.

Curriculum Development

Development of the Institute's curriculum began with the identification of skills to be addressed. These skills were sub-divided into those specific for science and mathematics and those cross-disciplinary skills applicable to all academic coursework. Science and mathematics skills included graphing, decimals, scientific notation, significant figures, measurement, scientific method/scientific inquiry, conceptual understanding, and laboratory skills. Curriculum-wide academic skills included identification of learning style, effective study techniques, note-taking, use of mnemonic devices, reading comprehension, organizational and time-management skills, written and oral communication skills, group dynamics, "brainstorming", test-taking skills, Internet and library research, creativity, seminar presentation, peer review, and most importantly, problem-solving and critical thinking skills.

Adapting the format of JPL's *Spaceset* and NASA's *International Space Settlement Design* into a logical progression over a three-week period and "nesting" skills to be developed in each phase constituted the second step in curriculum development. Four major phases were identified: (1) The Request for Proposal – Group Dynamics and Brainstorming; (2) Determining Settlement Needs – Scientific Inquiry and Research; (3) Formalizing the Design – Conceptual Understanding and Creativity; and (4) Presenting the Proposal – Communication and Peer Review.

The final step was the development of an assessment rubric to be used in calculating grades. The rubric assigns points based on levels of accomplishment:

Low Level Accomplishment = 1 – 4 points
Medium Level Accomplishment = 5 – 7 points
High Level Accomplishment = 8 – 10 points

Ten criteria are scored:

Extent of Background Research
Punctuality (Organized/Work Handed in On Time)
Extent to Which Proposal Areas Were Addressed
Quantity and Relevancy of Information
Team Participation
Depth of Knowledge on Topic(s) Assigned
Ability to Answer Questions
Effective Use of Visual Aids
Professionalism of Presentation
Creativity

Assessments are independently conducted by four groups: Peer Review from members of the student's group/corporation; Peer Review from students outside of the corporate group; a panel of three NASA judges; and evaluation by the two Institute teachers. Each of the four assessments receives equal weight in calculating the student's final grade.

Space Settlement Design Summer Institute

Phase One: Request for Proposal – Group Dynamics and Brainstorming.

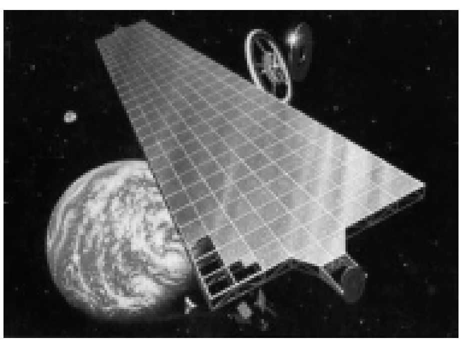
On the first day of the Institute participants are given an overview of the Foundation Society and its Request for Proposal (adapted from JPL's *Spaceset* materials). The RFP requests "corporations" to submit a written proposal and an oral presentation for the design, development, construction, and operation of the first Space Settlement Community in Earth orbit. The settlement's purpose is to provide infrastructure for accelerated development of space resources. The student corporations are to include the following in their proposal:

1. Description of the overall design, development, and construction of settlement. Description must include recommendation of an orbital location; reasons for its selection; rotation required to achieve a 1 g environment; where the 1 g environment exists; source of construction materials; construction timeline; and schedule for completion/occupation of the settlement.
2. Settlement Facilities – safe, pleasant living/working environment for 10,000 full-time inhabitants and 1,000 transients. The design must specify utilization of interior space (residential, industrial, commercial, etc.); external and internal dimensions; and major structural components.
3. Operations - housing, food production, electrical power generation, communication systems, internal transportation systems, climate control, and solid waste and water management.
4. Provision of services residents could expect to find in a comfortable suburban environment.
5. Automation support necessary for all facility and community operations.
6. Marketing plan for financial self-sufficiency.

After the overview, students draw “numbers” placing them in one of eight “corporations consisting of nine to ten students. Before the corporate “breakout session,” guidelines are provided for the “brainstorming phase.” Each corporation is provided with a classroom, an overhead projector and transparencies, and a chalkboard. By the conclusion of the first day, corporations are expected to “brainstorm” settlement facilities, identify corporate officers (CEO and Directors of Structural Engineering, Operations Engineering, Human Engineering, Automation Engineering, Astrobiology, Materials Procurement, and Finance), and develop an agenda for the second day. During the remainder of the first week of the Institute, corporations are allotted individual research and corporate meeting time periods to further develop their proposal and produce a timeline for completion of all parts of the proposal. Reference materials are provided and computers made available for Internet searches.

Students are also introduced to the scientific method during the first week. A Wisconsin Fast Plant activity, The Hypocotyl Hypothesis, provides the opportunity to apply the steps of the scientific method using gravity and light as variables. Participants gain useful data to assist in the design of further experiments that will contribute to the design of a food production facility for the settlement. Participants also learn how to measure surface area, volume, and density. They will use these skills later to calculate the volume of the settlement and its internal atmosphere. Scientific notation and decimal skills are incorporated in calculations of rotational speed required to achieve a 1 g environment. High school physics students assist students in the mathematical computations and the physics concepts involved.

Phase Two: Determining Settlement Needs – Scientific Inquiry and Research



During the second week corporations focus on scientific inquiry-based experiments providing data for their decisions as to settlement needs. The Director of Materials Procurement conducts flame tests for specific ions to determine what asteroid (from a group of seven potential asteroids) to mine for construction materials. Participants attend a seminar on mass drivers and the costs of transporting materials from Earth aboard the space shuttle. The Director of Astrobiology investigates transpiration, dissolved oxygen/primary productivity, and habitat selection behaviors. The Director of Human Engineering conducts studies on the physiology of the circulatory system and the effect of temperature changes on the heart rate of *Daphnia*. The Operations Engineering Director conducts qualitative tests on carbohydrates, lipids, and proteins exploring the nutrition requirements for settlement inhabitants. The Automation Engineering Director conducts DNA fingerprint analyses on potential settlers. A minimum of two other corporate members assists in each of the experiments. Using their newly acquired graphing skills, the Directors present their research findings to their corporate group and the group collaborates in the design of additional experiments investigating variables the group deems important for their proposal.

Phase Three: Formalizing the Design – Conceptual Understanding and Creativity

During the latter part of the second week and beginning of the third week, corporations begin formalizing their design. This is a massive undertaking requiring participants to: (1) determine needs for asteroid/moon mining; (2) determine which materials will be brought from Earth vs. those bought by mass driver from the moon/asteroids; (3) write "contracts" with subcontractors; (4) determine the number of workers and facilities required for the construction phase; (5) apply experimental findings to design of the agricultural food production facility; (6) apply their understanding of physiological/psychological needs of settlers to facility design; (7) calculate the volume of food required for 10,000 inhabitants, including space, irrigation, and light requirements; (8) determine total living space for colonists and transients; (9) develop safety systems ensuring survival in the event of breach of hull or life support system failure; and (10) devise commercial plans for financial self-sufficiency. This phase challenges the students' conceptual understanding and encourages their creativity. Participants also face the "real world" frustration of corporate members who fail to complete their assigned tasks. Each corporation has to face this problem and come up with solutions. This really tests the "mettle" of the CEOs. Participants also receive instruction on the use of Microsoft's *Powerpoint* software, on downloading images from the Internet, and guidelines for oral presentations.

Phase Four: Presentation of Proposal – Communication and Peer Review

On the final day of the Institute each corporation is allotted twenty minutes for the proposal presentation. Each group member is responsible for presenting his/her section. Participants are required to supplement their presentation with overheads. A panel of NASA judges provides technical expertise in judging the proposals and conducting the post-presentation question session. Written proposals are also submitted for evaluation.

Most corporations emphasize tourism as their main marketing plan. They produce elaborate brochures including shuttle schedules, tours, and mini-vacations. Several corporations take advantage of their research on asteroid/moon mining and materials processing to offer these as financially prosperous endeavors. Many include "contracts" for the purchase of products.

A detailed budget summary, initially a part of the planned activities, has been deleted. Participants are unable to fulfill this requirement, as they have no frame of reference for such large sums of money. Corporations are asked to provide approximate cost-breakdowns for some phases, including transport of materials to build the settlement. Students rapidly gain an appreciation of huge budget NASA requires for its space missions.

At the end of the day, each participant is provided with the assessments completed by each of the four groups: the NASA judges, the Institute instructors, the peers in their corporation, and their peers outside of their corporation. They also receive a letter, which they are asked to share with their parent/guardian, recommending which biology program they should enter in their freshman year

Summary

Space Settlement Design is an exceptionally adaptive unifying theme for skill development in middle and high school students. Coupled with a diversity of "hands-on" scientific inquiry experiences, students maintain a high level of motivation not only throughout the three-week Summer Institute, but continuing throughout the academic school year. The outstanding materials developed for JPL's *Spaceset* and NASA's *International Space Settlement Design* competitions provide a strong framework classroom teachers can adapt to meet their specific curricular needs. Adaptable to any grade and/or ability level, we believe the Space Settlement Design Institute offers a unique model for the enhancement of science and mathematics education in the 21st Century.

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