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"The Greenhouse of The Future": Using a Sponsored Competition in a Capstone Course

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(DRAFT)

Horticulture employers seek graduates who have the capacity to exercise sound judgement and make reasoned decisions when faced with difficult dilemmas to which there are no simple solutions and no experts to provide the answers. According to a University of Nevada, Reno, College of Agriculture survey (1989), employers are looking for individuals with problem-solving and logical reasoning skills, written and oral communication skills, teamwork and interpersonal skills, and technical skills. Of these desired skills, only technical skills were judged as being adequately provided by the current education system. It seems that much of the undergraduate experience has emphasized knowledge accumulation with only limited exposure to complex real-life problems. The Advisory Committee to the National Science Foundation recently recommended that science, math, engineering and technology faculty "build inquiry, a sense of wonder and the excitement of discovery, plus communication and teamwork, critical thinking, and life-long learning skills into learning experiences" (1996). Such curricular reviews and surveys often result in the widespread development and offering of capstone courses within university colleges (Rhodus and Hoskins, 1995). Capstone experiences seek to provide students the opportunities they need to develop the workplace skills employers expect and frequently focus on the following educational outcomes (Magner, 1990).

1. Critical thinking/problem solving skills: inquiry, problem identification, information assimilation, integration, and application
2. Teamwork skills: interaction with colleagues, leadership development, interpersonal competence, decision-making ability

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3. Communication skills: ability to describe and defend problem scenarios, analysis and management decisions both orally and in writing
4. Experience with current issues and problems: exposure to real-life problems without "correct" answers, analysis of larger philosophical questions and societal implications

Faculty developing capstone courses or integrating capstone experiences into existing courses, usually seek to de-emphasize certain content areas and replace them with classroom activities that teach toward the objectives stated above. This is often accomplished via case studies (Schramm, et al., 1994; Davis, 1992), special classroom or laboratory projects (Danneberger, 1994; Levy and Graham, 1993), computer simulations (Seibert and Vorst, 1997, Plouffe et al., 1994), or research projects (Walker, 1991; Lanza et al., 1988). An additional, but often underutilized vehicle available to better prepare graduates for the changing global workforce is the sponsored competition.

The greenhouse of the future competition

In December, 1995 the Department of Energy's (DOE) Agriculture & Food Technologies Program at the Idaho National Engineering Laboratory (INEL) together with the Epcot Center, Lake Buena Vista, FL, announced the "Greenhouse of the Future Competition". The objective of the competition was to provide an opportunity for U.S. university students to conceptualize, design, integrate, fabricate, and demonstrate innovative greenhouse or controlled environment ideas. The competition sprang from an interest by sponsoring agencies in promoting the development of environmentally sound, new technologies for greenhouse food production. The competition encouraged the formation of interdisciplinary student teams under the direction of an advisor(s). Team proposals were judged by greenhouse and/or technology specialists from University faculties, the commercial greenhouse industry, the Department of Energy, and the American Society of Agricultural Engineers. Proposals were to address one of the following greenhouse technology themes or present an integration of all three.

1. Greenhouse architecture and passive energy systems: innovative materials and architectural designs that improve the energy and plant growth efficiency of greenhouses including the use of energy saving covers, energy saving designs addressing ventilation or heating/cooling capacity, and sensors and novel control systems

2. Greenhouse infrastructure and active energy systems: energy requiring systems to increase overall efficiency, increase worker safety, reduce pollution, increase crop production, or improve product quality including nutrient and water delivery systems, air-handling and ventilation systems, and novel production system design

3. Biological systems: using biological means to improve crop production and energy efficiency including integrated pest management, crop selection strategies, and biological treatment systems

The competition announcement was posted fall 1996 as a home page on the DOE web site: WWW.STL.DOE.GOV, and was open to students at all U.S. universities/colleges. The competition was organized into the following three stages.

Stage 1

December 1995: Competition opens. Teams assemble, brainstorm, conceptualize ideas, review literature and existing technology, and formulate a five page proposal.

Stage 2

February-April 1996: Announcement of those teams proceeding to stage 2. This stage includes up to five finalist teams. Each finalist team receives \$500, plus a small greenhouse kit to modify. Teams proceed to prototype, develop, test technology concepts, perform experiments, and gather and analyze data in the modified greenhouses. The equivalent of a research publication is written and submitted for review.

Stage 3

May-June 1996: Winner announced. The winning team displays their greenhouse at Epcot '96 International Flower and Garden Festival, receives travel assistance and accommodations at a Walt Disney World Resort and receives a \$10,000 grant for greenhouse research programs at the winning university.

Montana State University "Field of Greens"

The Greenhouse of the Future competition was presented to students of PSES 435, Greenhouse Management at the beginning of spring semester, 1996. Greenhouse Management is a capstone course in the Department of Plant, Soil, and Environmental Sciences and is required within the Horticulture Science option of the Bachelors of Science, Horticulture degree. Guidelines of the competition were discussed and students were given the opportunity to volunteer for the project. Student involvement in the competition was not mandatory and no extra-credit was given.

The course structure was not modified to accommodate the competition, rather the competition was offered as an addition to the course, open to those wishing to participate. Both authors served in an advisory capacity, helping to organize team members, providing questions to explore, and assisting in keeping the project on track.

Nine students representing the majors of Horticulture, Soils, and Bioresource Engineering became the Montana State University team. Initial brainstorming meetings focused on identifying regional food crop production problems and conceptualizing possible solutions within the established competition parameters. Important questions raised by the team included: how can northern market vegetable growers extend the growing season from the current three month frost free period, while avoiding energy intensive systems? do niche markets exist for crops specifically adapted to the environmental stresses associated with the northern Rocky mountain region?, and can environmentally neutral production systems be developed for small greenhouses? From this discussion, the team chose to incorporate three objectives into their proposal.

1. Development of energy retention systems specifically designed for simple growing structures.
2. Production testing of alternative, stress tolerant crops adapted to cool season production and the stresses imposed by small greenhouses.
3. Development and testing of an environmentally neutral growing system that minimizes irrigation/fertilizer runoff and relies on pest resistant species and sensible biological pest control.

The students conducted an extensive literature search on active and passive heating of solar greenhouses, stress tolerant crop species suitable for greenhouse production, and energy efficient greenhouse components and designs. The team chose Mesclun salad green species for production testing in the experimental greenhouse. Mesclun salad greens are a high value, temperature stress tolerant crop suitable for production in greenhouses. Species such as arugula, endive, and mizuna require reduce production inputs and are becoming popular additives to salads in gourmet restaurants. High retail prices and the relatively short shelf life of the Mesclun greens make them attractive for regional production. Reflective of the crop selected for study, the team eventually chose to dub the M.S.U. entry the "Field of Greens".

The literature review revealed that few passive solar greenhouse studies had analyzed the effectiveness of combining several collection-retention techniques in simple growing structures. The team felt that the "Field of Greens" system should be a hybrid design, utilizing passive energy retention technologies such as infrared coverings, heat retention curtains, and rock pile heat storage, in an unheated cold frame production system. After the design was conceptualized, students produced an Autocad-generated schematic of the "Field of Greens" greenhouse (Fig. 1). This, along with a five-page proposal that included objectives, literature review, and summary of proposed new technology application, was submitted for review.

During February, 1996 the M.S.U. team was selected to proceed to stage 2 as a finalist in the competition. A greenhouse kit was shipped to campus and the team proceeded with construction (Fig. 2). The greenhouse as delivered was modified to maximize the collection, retention and

utilization of solar radiation through the use of double layer 'ir' film, a thermal curtain and a rock pile heat storage system (Fig. 1). Upon completion of greenhouse modifications, the Mesclun crop was placed in the greenhouse and a test production period commenced on April 15, 1996 and ended on May 5, 1997 (Fig. 3). Hourly average air temperature was recorded at four locations during the study with temperature probes. Students collected and summarized the recorded data and charted it graphically (Fig. 4). Students were then given the opportunity to discuss the research results in the form of a research report submitted to the judging team in April, 1996. The project culminated with the selection of the "Field of Greens" as the winning entry and a trip to the Epcot Center to showcase the project (Fig. 6).

Conclusions

Educational objectives of capstone courses such as critical-thinking and problem-solving skills are among the most cited needs in curriculum revitalization efforts (Goodman, 1992; Merritt and Hamm, 1994; Pauker, 1987). Sponsored competitions present an important vehicle for achieving these educational objectives. Opportunities such as the Greenhouse of the Future Competition provide students a diverse range of critical experiences not easily simulated in traditional classroom settings. The students achieved a great sense of accomplishment and satisfaction by converting their ideas into proposals, developing proposals into experiments, tracking the data generated by the experiments and translating that data into a meaningful communication locally (Fig. 5) and to the scientific community at large (see Appendix A). Most of these important learning experiences would have remained as components of the project even if the team had not advanced as the winning entry.

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Fig. 1. Front view schematic of the Montana State University "Field of Greens" passive solar greenhouse. Illustration depicts modifications including rockbox, heat retention shade cloth and 2-layer 'ir' film. Circles indicate temperature measurement locations.

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**Idaho
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Sonic Temperature Sensor for Food Processing (Draft)

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