priced flowering pot plants.”

“Maybe we should just stop selling to the retailers who were complaining,” Samantha said.

Chloe liked that idea, but wondered how they could replace any lost customers. Should they expand their shipping area? That would mean expanding their delivery responsibilities and possibly purchasing a larger truck. Chloe was already too busy with growing and transporting all the plants to the existing customers. Should they try to get into the mass market and sell low-quality plants like some of the other growers? Maybe they should consider growing some other crop.

“One option would be to stop growing poinsettias altogether and only produce bedding plants and perennials,” Chloe said. “Both are popular almost all year and seem to be growing in popularity with the demand for landscape color. However, the bedding plant industry has become somewhat crowded in the past few years.”

“But aren’t the poinsettias the best plant to grow in the off-season?” Samantha asked. “Plus the poinsettias help keep us in contact with our buyers, helping maintain orders for spring bedding plants. What would our employees do in empty greenhouses? You know we must employ them full time or they will quit.”

All in all, total sales at Two Sisters Greenhouses were comprised of 60% from bedding plant sales sold May through July, 30% from poinsettias sold November through December, and ~10% from garden mums sold August through September.

Chloe and Samantha pondered over what other alternative crops they could produce during a season that was dominated by one plant. There were many other questions left unanswered and many decisions that needed to be made very soon. Will the Scrooge ruin Christmas this year or can Chloe and Samantha make some changes that will maintain this young and successful greenhouse operation?

Interpretive or teaching note

This decision case was designed to help students understand critical management aspects of the horticulture industry.

Growers are faced with many issues other than those pertaining to production. They must decide how to market their product and make enough profit to justify growing the crop. The decisions that Chloe and Samantha make will be made as a team because both have an equal stake in Two Sisters Greenhouses. Therefore, dividing students into teams of two is suggested for this case study. Suggested issue-oriented questions for this specific case include the following:

- Can Chloe and Samantha cut their production costs?
- Is the wholesale price they are charging their customers unreasonable?
- Should Two Sisters Greenhouses start their own propagation facility and sell poinsettia cuttings and finished plants?
- Should Chloe and Samantha grow more plants at a lower quality and sell for a lower price?
- How would they find out about the newer poinsettia cultivars and cultural requirements?
- Should they change their marketing strategy by dropping some customers and including others?
- Should Chloe and Samantha try alternative crops?
- If they do try alternative crops, should they stop growing poinsettias or grow poinsettias in addition to other crops?
- What else could Chloe and Samantha do to retain the current profit margin and still produce a quality product?

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

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SUMMARY. Horticulture students often lack practical experience integrating information from diverse sources to solve complex real-life problems. Capstone courses seek to remedy this by giving students an opportunity to demonstrate a range of workplace skills such as teamwork, effective communication, and critical thinking. Sponsored competitions provide educators with an active-learning framework into which the goals of a capstone course can be developed. The Greenhouse of the Future competition allowed undergraduate students to conceptualize, develop, and prototype innovative greenhouse designs in a national competition venue. This article explains the guidelines of the Greenhouse of the Future competition and discusses how the competition was integrated into the capstone course *Greenhouse Management*.

Horticulture employers seek graduates who exercise sound judgement and make reasoned decisions when faced with complicated dilemmas. According to a University of Nevada-Reno College of Agriculture survey (1989), employers need individuals skilled in problem solving and logical

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reasoning, written and oral communications, teamwork and interpersonal cooperation, and technical applications. The Advisory Committee to the National Science Foundation (1996) 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 lifelong learning skills into learning experiences." Such curricular reviews and surveys often result in the development of capstone courses within university college curricula.

Capstone experiences build on skills acquired in earlier courses, provide students the opportunities they need to develop expected workplace skills, and frequently focus on the following educational outcomes (Magner, 1990; Rhodus and Hoskins, 1995):

- 1) Critical thinking and problem-solving skills: inquiry, problem identification, information assimilation, integration, and application.
- 2) Teamwork skills: interaction with colleagues, leadership development, conflict resolution, decisionmaking ability.
- 3) Communication skills: ability to describe and defend problem scenarios and management decisions 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.

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). Faculty developing capstone courses or integrating capstone experiences into existing courses may deemphasize certain content areas and emphasize classroom activities that teach toward these objectives. This is often accomplished via case studies (Davis, 1992; Schramm et al., 1994), special classroom or laboratory projects (Danneberger, 1994; Levy and Graham, 1993), computer simulations (Plouffe et al., 1994; Seibert and Vorst, 1997), or research projects (Lanza and Smith, 1992; Walker, 1991). Sponsored competitions represent another tool for achieving these educational objectives. Keeton (1983) stated "The best learning results in an interplay be-

tween theory and experience, idea and application, reflection and encounter."

We believe that competitions represent an important vehicle to prepare graduates for the requirements of the changing global workforce. Several professional organizations currently have undergraduate paper and poster competitions, including ASHS, the American Dairy Association, and the Institute of Food Science and Technology. Other competitions emphasize technical or discipline-related performance skills such as those sponsored by the Associated Landscape Contractors of America (ALCA). While these competitions represent a valuable undergraduate experience, they may not provide the student with experience solving complex problems in a competitive venue and may not be easily assimilated into a classroom setting. Sponsored competitions such as the recent Greenhouse of the Future are easily incorporated into existing courses and offer a range of experiences more compatible with the goals of a capstone course.

Greenhouse of the Future competition

In December 1995, the Department of Energy (DOE) Agriculture and Food Technologies Program at the Idaho National Engineering and Environmental Laboratory (INEEL) together with the Epcot Center, Lake Buena Vista, Fla., announced the Greenhouse of the Future competition. The objective was to provide an opportunity for U.S. university students to conceptualize, design, fabricate, and demonstrate innovative greenhouse or controlled-environment ideas. The competition sprang from the interest of the sponsoring agencies to promote the development of new, environmentally sound technologies for greenhouse food production. The competition encouraged the formation of interdisciplinary student teams under faculty advisorship. Team proposals were judged by greenhouse or technology specialists from university faculties, the commercial greenhouse industry, DOE, 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 ma-

terials 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 and cooling capacity, and sensors or 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 1995, on the DOE web site (www.stl.doe.gov) and was open to students at all U.S. universities and 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 and submit a five-page proposal. Stage 2: February–April 1996. Announcement of those teams proceeding to Stage 2, which includes up to five finalists. Each finalist 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 their modified greenhouse. The equivalent of a research report 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.

Montana State University (MSU) Field of Greens

The Greenhouse of the Future competition was presented to the 35 students of PSES 434 Greenhouse Management at the beginning of spring semester 1996. This is a capstone course

Fig. 1. Students constructing the competition greenhouse kit.

in the Department of Plant, Soil, and Environmental Sciences and is required within the Horticulture Science option of the Bachelor of Science degree in Horticulture. We, the instructors, discussed competition guidelines with the students, who were then given the opportunity to volunteer for the project. Student involvement in the competition was limited to those enrolled in the course and was not mandatory. No extra credit was given for competition participation. The course structure was not modified to accommodate the competition; the competition was offered as an additional project of the course, open to those wishing to participate. Both authors served in an advisory capacity, helped organize team members, provided questions to explore, and assisted in keeping the project on track.

Nine students representing majors in Horticulture, Soils, and Bioresource Engineering made up the MSU team. Initial brainstorming focused on identifying regional food crop production problems and conceptual-

izing possible solutions within the established competition parameters. Several important questions were raised by the team. How can northern market vegetable growers extend the current 3-month frost-free growing season while avoiding energy intensive systems? Do niche markets exist for crops specifically adapted to the environmental stresses associated with the northern Rocky Mountain region? Can environmentally neutral production systems be developed for small greenhouses?

From this discussion and literature review, the team chose to incorporate the following objectives into their proposal:

- 1) Development of season-extending, 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 and fertilizer runoff and relies on pest-resistant crops and sensible biological pest control.

The students conducted a literature review of 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 a mixture of salad greens for production testing in the experimental greenhouse due to their high commercial value, temperature stress tolerance, and suitability for greenhouse production. Species such as arugula (*Eruca vesicaria* subsp. *sativa* L.), upland cress (*Barbarea verna* Mill.), and mizuna (*Brassica juncea* L.) require reduced production inputs and are becoming popular additives to salads in gourmet restaurants. High retail prices and the relatively short shelf life of these crops make them attractive for regional production. Reflective of the crops selected for study, the team eventually chose to dub the MSU entry the Field of Greens.

The literature review revealed that few passive solar greenhouse studies had analyzed the effectiveness of combining several collection-retention

Fig. 2. A completed field-of-greens greenhouse after installation of season-extension modifications during production testing of the salad greens crop, 15 Apr. to 5 May 1996, Bozeman, Mont.

techniques in simple growing structures to extend the growing season. The team believed the Field of Greens system should be a hybrid design, using 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 a computer-generated schematic of the Field of Greens greenhouse. The design, along with a five-page proposal that included the literature review, objectives, and a summary of the proposed new technology, was submitted for review.

In February 1996, the MSU team was selected to proceed to stage 2 as a finalist. A 12 × 12-ft greenhouse kit was shipped to campus and our team proceeded with construction (Fig. 1). The greenhouse as delivered was modified to maximize the collection, retention, and use of solar radiation through the use of double-layer infrared film, a thermal curtain, and a rock-pile heat-storage system. Upon completion of greenhouse modifications, the crop was placed in the greenhouse and a test production period began on 15 Apr. and ended on 5 May 1996 (Fig. 2). Hourly average air temperature was recorded at four locations during the study using temperature probes wired to a datalogger. The recorded data was collected, summarized, and charted graphically. The students witnessed how their modifications affected the thermal performance of the greenhouse and extended the growing season by ≈3 weeks. The team presented these project results in the form of a research report submitted to the judges in May 1996. The Field of Greens was selected as the competitions' winning entry just before the end of the spring semester. The project culminated with members of the MSU team traveling to the Epcot Center to showcase the experimental greenhouse and report on the results during the International Flower and Garden Show, Spring 1997.

Conclusions

Opportunities such as the Greenhouse of the Future competition created an optimal learning framework by offering a diverse range of capstone experiences not easily simulated by other methods in traditional classroom settings. The competition placed the

students in a setting that challenged and enhanced their problem-solving, written, and oral communication skills and ability to function as a team. Additionally, students were exposed to the cooperative functioning of a university, governmental agency, and related industry in a competitive arena. This exposure was valuable in that it represented the first contact these undergraduate students had with the extramural funding process. Playing a role in securing a \$10,000 grant for future horticulture research within the Dept. of Plant, Soil and Environmental Sciences was a gratifying experience for the team members. The hands-on nature of the project, together with the potential reward of winning the competition, contributed to a high level of enthusiasm among the students during the project. Several students even maintained active involvement with the continuation of the research after the conclusion of the competition.

We believe that many components of the competition experience were valuable even if the MSU team had not been named a finalist. This was due, in part, to the three-stage design of the competition. Activities such as brainstorming sessions, literature searches, and proposal development occurred in the first round.

Another issue specific to this type of competition deals with student participation. It is difficult to assess whether student learning and satisfaction with the project would have remained as high if participation had been much higher. Optimally, all students in a capstone course would have a part in the learning opportunities presented by the inclusion of a competition. Mandatory involvement in such a project, however, may be difficult to manage in larger classes. Allowing students the option of taking on an additional course project is an excellent means of engaging the highly motivated student in the application of course concepts. In this example, three of the nine students on the MSU team could be characterized as nontraditional or adult learners. The competition component of the course allowed them to integrate previously gained life experiences into the course. Several motivational factors such as attitude, need, stimulation, competence, and reinforcement have been shown to have a substantial impact on adult learner outcomes (Wlodkowski, 1985).

It is possible that the competition environment enhanced these motivational factors.

The ability of the American higher education system to teach students critical thinking and problem-solving skills has been questioned (Baron and Sternberg, 1987) since the undergraduate experience has emphasized knowledge accumulation and memorization with only limited exposure to complex real-life problems. Overemphasizing memorization keeps students at the lowest level of learning (Whittington and Newcomb, 1992). Although increased learning among student participants was not formally measured, we believe this project was a valuable teaching tool. Postcompetition interaction with the participating students revealed the unanimous opinion that such a problem-based experience enhanced their ability to appraise problematic situations constructively and objectively. The following quote is representative of comments made by most of the team members: "The Greenhouse of the Future competition was a very worthwhile and valuable experience for me. It gave a diversified group of undergraduate students the challenge to come up with an original project plan and then actually put it together to see how well it worked. Most undergraduate programs at MSU don't regularly offer such an opportunity. I feel extremely fortunate to have taken part in this project."

Improving thinking skills might be a more important educational goal than disseminating knowledge in the classroom. Competitions can help students learn a number of explicit thinking skills associated with problem solving. Students can learn how to analyze a problem conceptually, formulate and evaluate various ways of seeking solutions, and put potential solutions into operation and evaluate their effectiveness. These types of hands-on experiences, planned so as to be integrated with overall course objectives, can also enrich students' experiences with regular course content. Sponsored competitions for undergraduates may be one more way to help students think on a higher level, and the green industry should be encouraged to sponsor more. Such cooperative efforts between industry and educators should become more commonplace and may produce graduates better equipped to handle the challenges of the real world.

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