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# Greenhouse Facility Management Experts Identification of Competencies and Teaching Methods to Support Secondary Agricultural Education Instructors: A Modified Delphi Study

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*In this study the Delphi technique has been used to develop a list of educational competencies for preparing secondary agricultural education instructors to effectively manage their school greenhouse facilities. The use of specialized facilities in agricultural education requires appropriate preparation of agricultural education teachers. The Delphi technique uses an anonymous panel of experts for suggestions and assessments aiming at consensus. Thirteen experts from multiple schools and universities took part in the investigation. The study used a series of three web–based questionnaires to determine competencies that teachers need to know, to be able to perform, and to identify effective teaching methods for teachers to obtain these competencies. The first round instrument consisted of three open–ended questions, and a series of questions to validate the background of the members of the panel. In the second round, respondents were asked to rate each competency and teaching method using a seven–point Likert–type scale. Median scores and interquartile values were calculated. Panel members were sent a copy of their individual responses as well as the group responses for review. In the third round, panel members were requested to indicate their level of agreement with each item using a five–point Likert–type scale.*

Keywords: Delphi, greenhouse management, competencies, agricultural education, teachers

## Introduction

Agricultural education teachers have access to specialized facilities and laboratories for teaching the content of the many curriculum areas. Specialized facilities and laboratories are often used to teach concepts and skills related agricultural mechanics, aquaculture, biotechnology, computers, forestry & natural resources, livestock, plant nurseries, and greenhouses (Newcomb, McCracken, McCracken, Warmbrod, & Whittington, 2004). Laboratory activities are viewed as "learning experiences in which students interact with materials and/or models to observe and understand the nature of agriculture and its underlying biological, physical, and social science components" (Myers, 2005, p. 14). Identifying the needs of teachers to effectively manage facilities and laboratories is important to the successful management of the local program. Roberts, Dooley, Harlin, and Murphrey (2006) recognize that managing, maintaining, and improving laboratories was a program planning and management competency of successful agricultural science teachers. Numerous studies have examined the agricultural mechanic laboratory management competencies of high school agricultural education teachers (Johnson & Schumacher, 1989; Saucier, Terry, & Schumacher, 2009). However, fewer studies in the agricultural education literature address the issue of determining what teachers need to know, and what competencies they to acquire to successfully manage greenhouse laboratory facilities at their local programs. (Lamberth, 1983).

Ornamental horticulture has emerged as one of the rapidly growing areas of production agriculture across the nation (Franklin, 2008; Lamberth, 1983; Watkins & Miller, 1984) and is gaining popularity among secondary agricultural education students (Galan, Lasanske, Warner, & DeLay, 2009). According to the National Agricultural Statistics Service (USDA, 2007) census of agriculture report, more than fifty

thousand U.S. farms were classified as horticultural operations. The value of sales from horticulture was nearly 6% of the total value of agricultural products sold in the U.S. in 2007. "Greenhouse, nursery and floriculture operations account for 2.5% of all U.S. farms but employ 4.9% of hired farm workers, and pay 13.3% of farm labor expenses" (USDA, 2007, p.1).

Research on greenhouse use in agricultural education has addressed topics such as comparing knowledge scores of students with a greenhouse experience to students without a greenhouse experience (Rothenberger & Stewart, 1995), determining the horticulture coursework requirements in preservice agricultural education programs (Boone, 2002), identifying the technical agriculture inservice topics needs of traditional and alternatively certified agriculture instructors (Roberts & Dyer, 2004), the use of a greenhouse facility for supervised agriculture experience (SAE) opportunities as a source of student motivation (Lasanske & Warner, 2008), and a description of the use of greenhouses by agriculture instructors in Arizona (Franklin, 2008). Lamberth (1983) conducted a study to identify and validate competencies needed by Tennessee horticulture instructors to manage greenhouse and landscape design. Thirty–five high school teachers participated in the Delphi study. Lamberth recommended that findings from research should be used for developing inservice training programs for teachers. In a study conducted by Franklin (2008), the majority (76%) of local agriculture programs in Arizona had or planned to have greenhouse facilities as part of their instructional program, but over half of the study respondents either had no formal university preparation experience related to horticulture (nearly 30%) or had completed six or less post–secondary units of instruction related to horticulture (28%). A lack of knowledge and experience with working with a greenhouse in a high school agricultural education program was one of the top–ranked barriers identified by the researcher as preventing teachers from being effective managers of their facilities. A recommendation from the researcher was that "professional development in the form of short courses should be developed to provide assistance to teachers with existing facilities to learn to become more proficient users" (Franklin, 2008, p. 44). Can the effective use of a greenhouse contribute to student achievement? Rothenberger and Stewart (1995) conducted a study to assess the effectiveness of instruction in horticulture using and not using a greenhouse laboratory experience with the traditional classroom lecture/discussion technique. Findings of their research were that students who received a greenhouse laboratory experience scored significantly higher on a knowledge test than did students who were taught the same lessons, without a greenhouse laboratory experience.

## Theoretical Framework

For a teacher to be successful in managing a specialized facility, they must acquire and develop proficiency in specific competencies. The theoretical framework for competency education may be found in the "Novice–Expert" literature (Chambers, Gilmore, Maillet & Mitchell, 1996; Dreyfus, 2004) where the teacher develops proficiency by going through stages of development. A five–stage model for skill acquisition (Dreyfus, 2004)

The progression from novice to expert is divided into five stages, each with its own set of rules for learning and performance: novice, beginner, competence, proficiency, and expert or mastery (Chambers et al., 1996; Dreyfus, 2004). "Competency is the midpoint on a continuum of professional growth that normally extends over a period of 10–12 years" (Chambers et al., 1996, p. 615). A student or teacher with little to no experience managing a greenhouse may label themselves as a novice. With increased knowledge and experience, the individual moves through the five stages until they have achieved the level of *competence* on their way to the level of *expert*. Undergraduate students in a teacher–preparation program or secondary teachers with no previous horticulture experience (Franklin, 2008) are likely to be in the novice and beginner stages. Over time, with experience and training, the teacher moves through the stages of competence and proficiency to the level of expert or mastery. This is accomplished with the aid of a mentor who has achieved the level of expert or mastery Chambers et al., 1996; Dreyfus, 2004).

Could identifying what teachers need to know and specific experiences to perform to effectively manage a greenhouse laboratory facility in an educational setting aid teacher

preparation programs identify appropriate courses? If so, what are effective methods for communicating this information to future teachers? If teachers can be moved from "novice to expert" in their knowledge and experiences can they be effective managers of greenhouse laboratory facilities?

Research Priority Five of the National Research Agenda for Agricultural Education and Communication (Osborne, 2007.) addresses the needs for research related to Agricultural Education in Schools: *5.4 Prepare and provide an abundance of fully qualified and highly motivated agriscience educators at all levels.* Preparing teachers to manage specialized facilities begins with identifying appropriate knowledge and skills (Johnson & Schumacher, 1989; Saucier et al., 2009). Should the preparation to teach horticulture–related courses and managing a greenhouse be included in the undergraduate coursework for future agricultural education teachers? The findings of this study will provide university teacher educators with information to prepare fully qualified agriscience educators to use a specialized facility in the delivery of horticulture

## Purpose and Objectives

The purpose of the Delphi survey study was to gather greenhouse laboratory management experts' perspectives on the development of a list of greenhouse laboratory management competencies needed by secondary agricultural education instructors, and preferred teaching methods to help teachers obtain the competencies. The specific objectives were:

1. To identify the greenhouse laboratory management competencies teachers must know to effectively manage their laboratories.
2. To identify the greenhouse laboratory management competencies teachers must be able to perform to effectively manage their laboratories.
3. To determine effective methods of providing experiences for secondary agricultural education instructors to develop greenhouse laboratory management competencies.

## Methodology

The Delphi method was selected for this study. It has come into extensive use within research and education, and there has been a review of use of this technique in agricultural education (Martin, 1998). Several examples of its use can be found in agricultural education research (Dyer, Breja, & Ball, 2003; Myers, Dyer & Washburn, 2005; Park & Rudd, 2005). Within competency development, the method has been used to identify lists of competencies need by secondary agricultural education teachers (Camp & Sutphin, 1991; Hudson, 1983; Johnson & Schumacher, 1990; and Miller & Foster, 1985).

There were several reasons for the selection of the Delphi method including anonymity (Figley & Nelson, 1988 as reported by Jenkins & Smith, 1994), geographical distance (Jenkins & Smith, 1994), cost, time, and the opportunity for participants to view the opinions of others. Buriak and Shinn (1989) suggested the Delphi method be used where a study progresses in phases, "each phase moving closer to satisfying objectives" (p.14). The phases of this research study are described below.

*Phase I: Identification of the Expert Panel*

The use of greenhouse facilities in an educational setting may not necessarily reflect the practices of found in the industry. Greenhouses in agricultural education settings may be used part–time to reflect the academic year instead of year–round (Franklin, 2008). The expert panel should be made up of individuals with knowledge and experience in managing greenhouse structures and facilities in an academic setting where the application of theory is the focus. These experts are the individuals whom secondary teachers may contact to ask technical questions about their high school greenhouses because (a) they are accessible, and (b) they are at an educational institution where teaching, research, and outreach is part of the mission. In order to identify an appropriate panel of experts the researchers relied on nominations from members of the American Association for Agricultural Education (AAAE). An email invitation was sent to the AAAE–listserv requesting the nomination of professional colleagues or teachers experienced in greenhouse management

in the education setting. A total of 29 names were submitted to the researcher.

This Delphi–method followed Dillman's *Total Design Method* (2007) and employed multiple points of contact in an attempt to obtain an acceptable response rate. The panelists were engaged in teaching greenhouse management in the university or high school setting in institutions located across the nation. All 29 were invited contacted via electronic mail and invited to serve on the panel. If the respondents accepted the invitation to participate, they could click on the link embedded in the email and be directed to the website hosting the questionnaire. The first page of the questionnaire invited the nominees to participate and asked for their consent. A total of 15 nominees (52%) agreed to participate and completed the first round instrument. When the number of members on the panel is 13 or higher, the reliability of the method will be at least 0.80 (Dalkey, 1969).

*Phase II: Collection of Opinion*

In the first round, the expert panel was asked to offer their responses to three open–ended questions. Two broad categories used were knowledge and skills. The first two questions focused on the knowledge and skills teachers would need to obtain to effectively manage greenhouse facilities. The third open–ended question asked panelists to identify effective methods of acquisition for obtaining the competencies. To establish and validate the expertise of the panel, participants were requested to complete a set of selected demographic questions. It was decided in advance to use only three rounds in this research study in order to avoid the dropouts that could be expected if more rounds were used (Edgren, 2006). Since limiting the number of rounds could prevent total consensus, 75% agreement was chosen as the consensus level. The results from round 1 were collected and checked for content validity by a panel of experts which university greenhouse management research specialists and a graduate student in controlled environment agriculture. The resulting list consisted of 54 knowledge competencies, 50 ability competencies, and 32 methods of acquisition.

In the second round, participants were asked to score the importance of the items on a Likert–type scale with 1 being *least important*, 2 being *of little importance*, 3 being *somewhat important,* 4 *moderate important*, 5 being *important*, 6 being *very important*, and 7 being *extremely important.* Results from round two were compiled and a new instrument was compiled for round three.

The questionnaire for round three contained three lists of the 54 knowledge, 50 ability, and 32 method acquisition competencies, and listed the median group rating, interquartile range (IQR) value for each competency, and the individual respondent's rating for each competency. The respondents were asked to rate each competency now knowing the mean group rating and their previous rating for each competency. Respondents were able to provide comments and change their ratings.

Questionnaire three contained all three lists of competencies and listed the median group rating and IQR value for each knowledge, ability, and methods acquisition competencies. In an attempt to reach final group consensus, the respondents were asked to indicate their level of agreement with each competency using a Likert–type scale with "1" being *strongly disagree*, "2" being *disagree*, "3" being *uncertain*, "4" being *agree*, and "5" being *strongly agree.* To determine the most agreed upon competencies, researcher–defined criteria were employed. Competencies that met the criteria of reaching a group mean score of 3.5 or higher were retained and are presented in the tables in the findings section.

Stone, Fish, and Busby (2005) recommend analyzing Delphi data using median and interquartile ranges to identify rates of group agreement and consensus. The use of interquartile ratings (IQR) provides the researcher with information "… about the variability in the data without being affected by extreme scores" (p. 247).

*Phase III: Analysis of Data*

Data were downloaded into Microsoft Excel ®, recoded and entered in SPSS 17.0 for Windows. The following anchors were used to describe the means for levels of agreement for all three lists of competencies: *strongly disagree* = 1.00 – 1.49; *disagree* = 1.50 – 2.49; *uncertain* = 2.50 – 3.49; *agree* = 3.50 – 4.49; *strongly agree* = 4.50 – 5.00.

## Findings

*Validating the Expert Panel*

Members of the expert panel were from the states of Arizona, Arkansas, California, Connecticut, Georgia, Idaho, Kentucky, Ohio, Oklahoma, Missouri, and Texas. The make–up of the panel was mostly male (62%) holding a doctorate degree (62%). The reported number of years' experience working with greenhouses ranged from less than five years (23%), six to ten years (15%), 11 to 19 years (15%), to 20 years and more (46%). Current rank or positions were self–identified as secondary agricultural educators (7%), university greenhouse specialists (7%), assistant professors (15%), associate professors (15%), full professors (15%), and greenhouse managers/coordinators (23%). All respondents were currently engaged in managing a greenhouse facility at an educational institution (100%).

*Knowledge Competencies*

The first objective of this study was to determine what teachers need to know in order to be able to effectively manage their greenhouse facilities. An open–end question posed was *What does a teacher need to know to effectively manage a greenhouse facility?* The panel responded with a list of 54 knowledge competencies. In the second round each panel member reviewed their individual responses and the group responses to each competency. Changes made were sent back to the researcher. For clarity of presentation, the competencies were grouped into clusters. For the knowledge competencies, the clusters were identified as *safety practices, horticultural practices, facility maintenance, certification, program management, and marketing.* In Table 1, panel members believe that knowledge competencies clustered as *safety practices* are important for teachers to know to manage greenhouse facilities – rating safety practices with a mean of 4.77. Panel members identified two safety competencies with a mean range of 4.77 to 4.38. These were related to student safety around the greenhouse facility. Knowledge of *horticultural practices* related to factors associated with production of plants

Table 1 is a listing of each competency including, mean agreement rating and standard deviation.

Table 1
*Delphi Round Three: What Teachers Need to Know to Effectively Manage a Greenhouse Facility (n=15).*

| Knowledge | *M* | *SD* |
|---|---|---|
| *Safety Practices* | | |
| Appropriate safety practices in the greenhouse | 4.77 | 0.44 |
| When to let students work in the greenhouse after spraying | 4.38 | 0.77 |
| *Horticultural Practices* | | |
| Plant growth. | 4.62 | 0.51 |
| Environmental factors affecting plant growth. | 4.38 | 0.65 |
| Pest management for common greenhouse pests. | 4.23 | 0.60 |
| Basic plant anatomy. | 4.23 | 0.93 |
| Disease management. | 4.15 | 0.55 |
| Propagation skills. | 4.15 | 0.80 |
| Weed control | 4.08 | 0.64 |
| Pruning and pinching skills. | 4.00 | 0.71 |
| Fertilization | 3.92 | 0.76 |
| Plant identification. | 3.85 | 0.69 |
| Nutrient deficiency symptoms. | 3.85 | 0.69 |
| Nutrient solutions for specialty crops/systems. | 3.77 | 0.73 |
| Soil media. | 3.69 | 0.85 |
| Plant physiology | 3.69 | 1.18 |
| Chemistry of nutrient solutions | 3.67 | 1.15 |
| Growth schedule of plants for year round production. | 3.62 | 1.26 |
| Pour thru method and testing for EC, pH. | 3.54 | 1.13 |

| | | |
|---|---|---|
| *Facility Maintenance* | | |
| Basic greenhouse equipment operation/maintenance. | 4.54 | 0.52 |
| Appearance of greenhouse is a direct reflection of teacher. | 4.31 | 0.63 |
| Greenhouse irrigation systems. | 4.23 | 0.73 |
| Operation of heating system | 4.15 | 0.55 |
| Operation of cooling system | 4.15 | 0.55 |
| Nutrient delivery control system and how it works, and troubleshoot. | 4.15 | 0.55 |
| Electrical systems in a greenhouse. | 4.08 | 0.64 |
| Automated greenhouse control systems. | 4.00 | 0.71 |
| Troubleshooting problems with environmental control systems. | 3.92 | 0.64 |
| Automated emergency sensor systems | 3.92 | 0.76 |
| Shade cloth use and installation | 3.54 | 0.88 |
| *Certification* | | |
| State & Federal laws concerning pesticides. | 4.00 | 0.71 |
| Qualify for state pesticide applicator's license. | 4.00 | 0.58 |
| State & federal laws concerning labor & labor safety. | 3.92 | 1.04 |
| *Program Management* | | |
| Basic math skills: greenhouse production computations. | 4.31 | 0.48 |
| Which crops students can be successful growing within one semester. | 4.23 | 0.60 |
| Balancing classroom instruction with greenhouse work time. | 4.08 | 0.64 |
| Budget planning and analyses. | 4.00 | 0.71 |
| Scheduling timing for planting to ensure desired plant size at defined times. | 3.92 | 0.86 |
| *Knowledge of maintaining an equipment & supply inventory.* | 3.83 | 1.03 |
| *Institutional policies of ethics and harassment.* | 3.77 | 1.09 |
| *Human resource management (volunteers, staff, etc)* | 3.69 | 0.85 |
| *Trends in the horticulture industry* | 3.62 | 1.04 |
| *Ordering and acquiring seeds, plugs and stock plants.* | 3.62 | 1.12 |
| *Marketing* | | |
| Pricing plant product | 3.77 | 0.93 |
| Popular crops that will sell to the public. | 3.54 | 1.20 |
| Marketing of greenhouse crops. | 3.54 | 1.27 |

*Note: agree = 3.51–4. , strongly agree = 4.51–5.00*

*Ability to Perform*

Question 2 of the first round instrument asked the panel to provide a list of competencies that teachers need to be able to perform to effectively manage their greenhouse facilities. The panel responded with a list of 51 competencies. Each panel member reviewed their individual responses and the group responses to each competency. Changes made were sent back to the researcher. Table 2 is a listing of each competency including the median rating, interquartile value, mean agreement rating, standard deviation, and rating descriptor.

Table 2.
*Delphi Round Three: Abilities Considered Essential to Effectively Manage Greenhouse Laboratories (n=13).*

| Ability to Perform | *M* | *SD* |
|---|---|---|
| *Horticultural Practices* | | |
| Recognize plant stress | 4.92 | 0.28 |
| Identify pests and how to control them. | 4.69 | 0.48 |
| Grow a plant of good quality to maturity | 4.69 | 0.48 |
| Watering and fertilizing effectively | 4.62 | 0.51 |
| Scout biweekly and correctly identify insects and diseases. | 4.38 | 0.65 |
| Identify plant health problems. | 4.38 | 0.51 |

| | | |
|---|---|---|
| Properly fertilize material. | 4.31 | 0.48 |
| Calculate correct fertilizer concentrations for injector. | 4.31 | 0.63 |
| Successfully grow a salable, blooming plant, not overgrown on sale day. | 4.31 | 0.95 |
| Prepare or control the nutrition program needed for the crop. | 4.23 | 0.44 |
| Diagnose and correct nutrition problems | 4.23 | 0.44 |
| Effective use of pest control methods | 4.23 | 0.83 |
| Perform typical cultural practices (pruning, training, etc.) for the plants grown. | 4.23 | 0.60 |
| Set up growing systems (pots, potting soil, hydroponics, etc). | 4.23 | 0.73 |
| Perform propagation of plant material. | 4.15 | 0.69 |
| Identify plant material | 4.08 | 0.76 |
| Implement IPM program that does not use harsh chemicals. | 4.00 | 1.08 |
| Observe changes in plants and operating systems | 3.77 | 1.01 |
| *Safety Practices* | | |
| Apply safety practices and procedures. | 4.85 | 0.38 |
| Maintain and repair a respirator and other PPE. | 4.00 | 0.91 |
| *Pedagogy* | | |
| Use the greenhouse for hands–on experiments | 4.46 | 0.66 |
| Connect careers to the greenhouse. | 4.23 | 0.60 |
| Balance the use of the greenhouse (i.e., who gets to use it for specific classes. | 4.15 | 0.80 |
| Teach students about all aspects of the greenhouse. | 4.00 | 0.82 |
| *Facility Management* | | |
| Program the environmental control system. | 4.54 | 0.52 |
| Manage temperatures in the greenhouse. | 4.46 | 0.52 |
| Initiate emergency cooling and heating during power failures. | 4.31 | 0.48 |
| Basic plumbing skills (assembly) | 4.23 | 0.44 |
| Repair irrigation equipment. | 4.23 | 0.73 |
| Repair broken irrigation lines. | 4.23 | 0.73 |
| Utilize and adjust control system to ensure proper environments /lighting. | 4.23 | 0.44 |
| Program the nutrient delivery system. | 4.15 | 0.55 |
| Program climate control systems with the set–points needed. | 4.08 | 0.49 |
| Calibrate fertilizer injector | 4.00 | 0.91 |
| Perform basic equipment maintenance: change a fan belt, replace cooling pads. | 3.85 | 0.55 |
| Select necessary sensors & control systems needed for the greenhouses facility. | 3.77 | 0.73 |
| Manipulate greenhouse coverings. | 3.77 | 0.93 |
| *Planning & Management* | | |
| Schedule work for students and volunteers | 4.31 | 0.63 |
| Set up and keep good records (repairs, pest problems, plant growth, etc.) | 4.31 | 0.63 |
| Generate funds from plant sales | 3.92 | 0.86 |
| Assemble a basic drip irrigation system. | 3.69 | 0.63 |
| Budget for replacement costs for equipment or glazing. | 3.69 | 0.63 |
| Organize space usage. | 3.62 | 0.77 |
| Be on–call 24/7 as long as the greenhouse is in operation. | 3.54 | 1.45 |
| *Communications* | | |
| Interact with faculty, staff, and students | 4.69 | 0.63 |
| Gain the support of school and district administration. | 4.31 | 0.63 |
| *Marketing* | | |
| Determine selling prices for crops that will provide enough funding to purchase plants/supplies for next year but still sell in their local market. | 4.00 | 0.91 |
| Effectively run a plant sale. | 3.85 | 0.90 |
| Create public relations from greenhouse | 3.85 | 0.99 |

*Effective Teaching Methods*

The members of the panel were asked to respond to the open–ended question, *What is the best method for teachers to obtain these competencies?* The panel provided 31 responses. During the second round, the panel was asked to rate each method using the 7–point Likert–type scale. The median and interquartile (IQR) values were calculated. Each panel member was sent a copy of their individual responses, as well as the group median responses to review and make changes. After receiving feedback from the panel, a subsequent round was posted. Each method was ranked by median value and IQR. The panel was invited to review the list and express their level of agreement on a five–point Likert–type scale. Table 3 presents the findings of the panel.

Table 3

*Delphi Round Three: Methods to Acquire Competencies to Manage Greenhouse Laboratories (n = 13)*

| Method of Acquisition | *M* | *SD* |
|---|---|---|
| *College Coursework* | | |
| Enrolling in horticulture courses | 4.38 | 0.65 |
| Completing a college course of study related to greenhouse horticulture and management, | 4.15 | 1.07 |
| Completing a student teaching experience – learn by observing others in the field. | 4.15 | 1.14 |
| *Workshops/Inservice* | | |
| Attending greenhouse–related short courses. | 4.15 | 1.07 |
| Participating in teacher inservice training | 4.08 | 0.49 |
| Participating in summer training programs | 4.08 | 0.49 |
| Attend day seminars related to greenhouse production. | 4.08 | 0.49 |
| Attend agriculture teacher state and regional meetings that offer related workshops. | 4.08 | 0.64 |
| Attending workshops on pest management | 4.00 | 0.0 |
| Attend workshops provided by greenhouse manufacturers. | 3.69 | 0.75 |
| Attend workshops provided by greenhouse control systems companies | 3.69 | 0.75 |
| *Internship Experience* | | |
| Completing work experience in a greenhouse | 4.54 | 0.52 |
| Serving an internship before graduation with reliable greenhouse operator. | 3.92 | 1.12 |
| Working part–time in a greenhouse facility. | 3.92 | 0.76 |
| Shadowing a greenhouse production manager as an internship | 3.77 | 0.83 |
| *Experiential* | | |
| To actually grow plants or crops | 4.54 | 0.66 |
| Conduct student project experiments in the school greenhouse. | 3.85 | 0.80 |
| Trial & error method; keep records and learn from mistakes. | 3.69 | 0.85 |
| *Field Trips* | | |
| Visit a neighboring agriculture department with greenhouses to get ideas. | 4.23 | 0.60 |
| Attend horticulture trade and garden shows | 3.69 | 0.85 |
| Attend industry trade shows and workshops | 3.62 | 0.96 |

*Note:* Agree = 3.50–4.49, Strongly Agree = 4.50–5.00

There were several teaching methods which were identified and rated by the panel as most effective for helping teachers to obtain competencies needed to effectively manage their greenhouse facilities. Items receiving a median value of 5, 6 or 7 were considered moderately to extremely effective and retained from second round to the third round for approval. The lower interquartile values indicate little variance among responses. For the purpose if interpreting the levels of agreement, real limits were applied (5.00 – 4.50 = strongly agree; 4.49–3.50 = agree; 3.49–2.50 = uncertain; 2.49–1.50 = disagree; and 1.49–1.00 = strongly disagree).

## Conclusions

One assumption of utilizing the Delphi method is that the respondents serving on the panel are knowledgeable of the subject (Johnson & Schumacher, 1989). For this study, the respondents must have experience in managing a greenhouse in an educational setting, rather than a commercial setting. Based an analysis of the demographics reported by the respondents, the researchers felt this assumption was met.

The knowledge–based competencies identified by the panel are their perceptions of what teachers need to know to be effective greenhouse facility managers. The panel reached consensus on 48 of 54 (89%; agree or strongly agree) of the competencies. The ability–based competencies identified by the panel are their perceptions of what teachers should be able to perform to effectively manage their greenhouse facilities. The panel reached consensus on 49 of 50 (98%; agree or strongly agree) of the competencies. For methods – acquisition of the competencies the panel reached consensus on 21 of 30 (70%; agree or strongly agree) methods.

Knowledge of safety related to students was the highest rated competency. Horticultural practices related to the environmental factors affecting the growth and production of plants rated highly with the panel. Operation and maintenance of the greenhouse facility were considered important for teachers to know, as well as certification requirements when dealing with pests and chemicals. Knowledge of program planning and management related to teaching classes, budgeting, scheduling, budgeting and product marketing was the remainder of identified competencies.

Ability competencies consisted of how to perform horticultural practices related to setting up a greenhouse for plant production including: media preparation, planting, water, fertilizing, thinning, pruning, harvesting, and packing. Facility operation and maintenance skills included the environmental system (heating and cooling) mixing and applying liquid fertilizers, shading, and troubleshooting and repair of electrical and water lines. Pedagogical skills included how to teach students using the greenhouse, developing lessons and activities related to the operation of the greenhouse, managing the greenhouse on the academic calendar, budgeting and purchasing, communicating with school staff and the public and marketing greenhouse products.

The methods which are most effective for providing teachers with a means of acquiring the competencies needed to effectively manage their greenhouse facilities are those that provide on–site experiences with hands–on learning activities. College–level course work combined with an internship experience (i.e., industry internship, or student–teaching experience with a teacher experienced in greenhouse operation and management) will help move teachers through the early stages of competence. Professional development inservice opportunities are effective methods of learning will guide from novice and beginner stages to the competence stage. Years of experience and guidance from veteran teachers will help move teachers to the later stages toward expert or mastery. Specific topics should include: the operation of specific environmental (heating and cooling) systems, irrigation and fertilization systems, pest identification, prevention, and elimination, and plant physiology (understanding the needs and responses of the plant to the environment), and successful marketing of greenhouse products.

## Implications

Are greenhouse laboratories as common a structure in secondary agricultural education programs as agricultural mechanic laboratories? Teacher–educators and state staff should assess their local programs to determine the number of such facilities in their states. States with local programs using greenhouse laboratories may be faced with the issue that teachers are ill–prepared to effectively manage their facilities (Franklin, 2008; Lamberth, 1983). Student achievement in horticulture can be enhanced by effective use of greenhouse (Rothenberger & Stewart, 1995) therefore; the preparation of future teachers must include technical coursework which includes a combination of horticulture courses and greenhouse facility operation. For teachers in the field, the professional development needs to focus on both operation and maintenance of existing facilities, and an understanding of plant physiology and growth. Local programs may have a greenhouse, but how are they being used and to what extent?

Experienced teachers should be identified and recruited to mentor newer and less–experienced teachers in the field; a series of professional development workshops should be offered during the summer or on weekends. The workshop topics should build upon each other and give teachers an opportunity to experience different teaching greenhouse scenarios.

University teacher–educators should attempt to identify if horticulture and greenhouse facility management courses are available for pre–service students. The faculty responsible for delivery of the courses should be consulted to determine the appropriateness of the content of the courses for preparing future teachers to operate greenhouse facilities for educational purposes. If not, are similar courses available at local community colleges, and can the courses count for transfer credit?

## Recommendations

Future research should be conducted to determine how important the identified greenhouse facility management skills are to secondary teachers. Follow up research should be conducted to determine if secondary teachers possess the competencies to manage greenhouse facilities, and to what extent do they practice the competencies. The use of an instrument such as the Borich Mean Weighted Discrepancy Scale (MWDS) (Borich, 1980) should be used to measure the importance of each of the knowledge and ability competencies. The findings should guide university technical course development and future professional development program needs for teachers of secondary programs with greenhouse laboratory facilities.

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