*Research Article*

# Skills Identification for Healthcare Facility Engineering Technicians

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**ABSTRACT**

The purpose of this research was to identify the technical skills that are necessary for competency as a facility engineering technician (FET) in the healthcare built environment. The Delphi method was used to draw upon the knowledge and experience of healthcare facility engineering managers and technicians to identify and prioritize baseline technical skills, as well as to identify proficiency levels for the skills. A total of 73 skills were identified as necessary for healthcare FET baseline competency including areas of wood, plastic, and composite; flooring; doors; plaster and gypsum board; mechanical support; fire support; plumbing; electrical; and safety and compliance. Of these 73 skills, 35 were deemed key with strong agreement consensus.

Successfully recruiting, training, and maintaining a competent FET workforce is essential but challenging for healthcare organizations, in part because of the lack of formal education programs and an unclear path of entry into the profession. The results of this research are valuable in that they can be used to develop training for the healthcare FET workforce. Trainers can use the findings of this research when developing curriculum and determining which skills to emphasize. Healthcare organizations can use the findings to assess current capabilities across staff, to determine whether there are gaps in needed skills and to begin developing strategic programs in response to the challenges of attracting and retaining competent FETs. This research suggests other types of jobs need to be examined to move toward developing a more complete understanding of the skills and capabilities necessary for the spectrum of the facility engineering workforce (from technical to managerial) to address attrition, recruitment, retention, and succession challenges.

## Introduction

Property owners, occupiers, and builders struggle to attract and retain facility engineering technicians and managers (Sullivan et al. 2010; Bigelow et al. 2017). Successfully recruiting and training new candidates to fill FET jobs is critical to any organization and particularly to those in the healthcare industry, in which the physical infrastructure directly supports medical operations and the needs of local communities (Shohet 2006; US Department of Veterans Affairs 2020). To fill existing or forthcoming professional job vacancies, most organizations recruit people from academic programs (Lindquist and Endicott 1986). Though there are vocational programs for trade work in facility engineering, they are declining in the United States as more individuals pursue higher education. Therefore, the pool of qualified FET workers is shrinking even while hiring demand grows (Benavot 1983; Call et al. 2018b, 2019; US Bureau of Labor Statistics [BLS] n.d.). Few academic programs are specific to FET workers because the role of an FET requires a general and broad understanding of overall building operations, with specific skills typically developed on the job (Call et al. 2018b; Brumbach and Clade 2013). For example, one of the largest cities in the United States appears to have only a single academic program for FETs (Gateway Community College n.d.). In this program, the majority of coursework consists of internships, a limited number of building trade skills are covered rather than providing a broader overview, and healthcare topics are not addressed. Training delivery through a formal academic program may also be challenging for healthcare organizations due to geographical constraints for FETs in more rural setting and academic calendar coordination that may not align with hiring cycles or work shifts.

The combination of workforce attrition and lack of formal training opportunities is problematic for facility engineering (*Evaluating the Value* 2017), especially in the healthcare industry because FET jobs are the typical point of entry into the facility engineering profession and the beginning of workforce development and succession (Call et al. 2018b). The purpose of the current study was to identify the technical skills necessary to achieve competency as an FET in the healthcare built environment. The study involved classifying skills that healthcare organizations should focus on when establishing talent development programs to improve recruitment, training, and job duties of healthcare facility engineering workers.

## Literature Review

An extensive review of literature indicates that limited research is available on the technical skills of healthcare FETs. The US BLS lists typical duties of FETs as inspecting, troubleshooting, repairing, and maintaining machines and buildings; another important duty is recognizing when a job is above an FET's skill level and requesting the expertise of a licensed tradesperson (US BLS n.d.). The US BLS (n.d.) provided a list of suggested competencies on which to develop an apprenticeship program for FETs; these competencies included assembling, disassembling, replacing, inspecting, testing, cleaning, adjusting, aligning, balancing, lubricating, troubleshooting, maintaining, and repairing mechanical equipment; operating moving or lifting equipment; reading technical information and laying out work; ordering materials; planning work procedures; fabricating and grinding parts; painting; supervising and training other employees; operating welding equipment; measuring distances; and estimating costs.

Brumbach and Clade (2013) provided detailed instruction on industrial maintenance work, organized by mechanical, electrical, and welding knowledge, as well as an introduction to proper safety procedures, the use of tools and fasteners, and how to read blueprints. Mechanical knowledge includes an understanding of how to repair and maintain power equipment, bearings, coupled shafts, seals, pumps and compressors, and piping systems. Electrical knowledge includes understanding electrical fundamentals, such as current, voltage, and resistance; proper use of test equipment, including a digital multimeter; and troubleshooting, maintenance, and repair of resistive electric circuits, power factors, wiring, transformers, motors, controls, drives, and lighting. Welding knowledge includes an understanding of gas and arc welding.

The American Society for Healthcare Engineering (ASHE, n.d.-a) offers training for FETs on how to help healthcare facilities improve energy efficiency. This training covers HVAC and building controls, boiler and steam systems, compressed air and fan systems, pump systems, electrical and emergency power systems, maintenance best practices, retro-commissions, and establishment of an environment of care. ASHE also provides healthcare facility technicians with training on proper functionality and inspection of specific healthcare building systems and equipment, including fire doors, HVAC controls, cooling water towers, air handling units, steam traps, shafts and chutes, medical gas cylinders, automatic sprinkler pipes and fittings, fire and smoke dampers, wet and dry pipe sprinkler systems, and portable fire extinguishers (ASHE n.d.-b).

ASHE (2018) described the essential technical knowledge that healthcare engineering directors need as they lead technical teams. This knowledge includes an understanding of applicable regulations, codes regarding design and construction, building systems (HVAC, electrical distribution, medical gas and vacuum) and how to evaluate their operation, energy management, and shutdowns. Call et al. (2019) outlined the core competencies for entry-level healthcare facility engineering managers: understanding of regulations, building systems, infection control, asset management, facility operations, construction management, conflict resolution, clinical operations and medical equipment, materials management, and environmental services. Although the literature identifies possible duties and competencies required of facility engineering workers in the built environment overall, it is unclear which technical skills are necessary for proficiency as an FET in healthcare. Additionally, it is unknown whether the literature contains sufficient detail about FET skills and proficiency expectations in order for an effective FET training program to be developed. Therefore, further research was needed in order to identify the technical skills and proficiency necessary to obtain competency as a healthcare FET.

## Methodology and Data Collection

The list of FET skills identified during the literature review are wide ranging, and some of the skills potentially are relevant to multiple types of facility engineering employees, such as technicians, plant mechanics, various types of building trade workers, and even some managers. In this study, to be more effective in selecting skills, the Delphi method was used. Sourani and Sohail (2015) and Hallowell and Gambatese (2010) explained that the Delphi method is an iterative research approach that secures feedback from experts through two or more rounds of structured questionnaires; the purpose of using this method is to obtain reliable results regarding a particular area of uncertainty. After each data collection round, the data were analyzed and summarized, with the objective of achieving group consensus (Figure 1).

### Participants

Twenty-nine people were selected to participate in this research. The participants resided in Arizona, Minnesota, or Florida. As the reliability of Delphi study results depends on selecting appropriate experts (Chan et al. 2001), each participant had at least a high school diploma, had at least three years of full-time facility engineering work experience, and were employed full-time in a large healthcare system; the average participant had completed some college or held a vocational certificate and had 18 years of full-time work experience in facility engineering. More than half of the participants (59%) were employed as facility engineering technicians, and the remainder (41%) were employed as facility engineering managers.

### Data Collection

Round 1 of data collection served as a brainstorming session to identify all potential baseline technical skills a competent healthcare FET needs. To collect data, a questionnaire was developed that included a list of skills from the literature review, organized according to the divisions in the Construction Specifications Institute's *MasterFormat* (2020). The participants were asked to

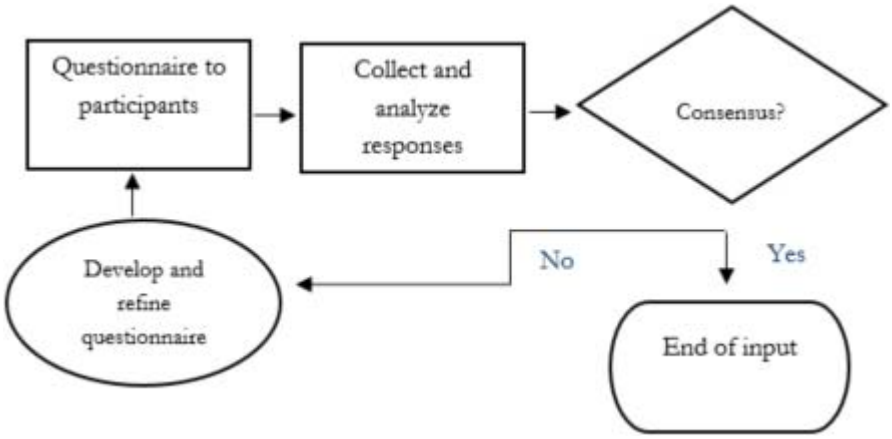


**FIGURE 1.—**Delphi method procedures

complete the questionnaire by indicating if any skills listed were wholly unnecessary or in need of clarifying detail and to identify any skills that were missing from the questionnaire. In completing the questionnaire, the participants were to think about the skills needed in order to achieve minimum technical competency as a FET working in an acute care hospital facility with approximately 350 beds and 30 plant operations employees (Call et al. 2018a).

The participants' responses were synthesized and used to develop a structured questionnaire that included a revised list of FET skills. In round 2 of data collection, the participants completed this questionnaire on Qualtrics. The participants were asked to rate on a Likert scale (ranging from 1 = *strongly disagree* to 5 = *strongly agree*) their level of agreement that a competent healthcare FET should be able to perform each skill. If a participant agreed on a skill ($>$ 3.0), the participant was then asked to select the expected performance proficiency level, using the following scale (NIH n.d.):

- Basic knowledge: Has common knowledge or an understanding of the basic techniques and concepts
- Limited experience: Has experience gained in a classroom and will likely need help when performing this skill
- Intermediate experience: Can successfully complete the task as requested but may need help from an expert from time to time
- Advanced experience: Can perform the actions associated with the skill unassisted and is recognized in the organization as a resource when difficult questions arise regarding the skill.
- Expert experience: Can provide guidance, troubleshoot, and answer questions related to this skill and the field in which the skill is used

### Consensus Criteria

As is common in facility engineering and management research, absolute deviation was used to measure consensus (Ameyaw et al. 2014). Consensus on each skill and its proficiency level was achieved if the absolute deviation was less than one unit on the Likert scale (Hallowell and Gambatese 2010). Agreement consensus was achieved if the skill had a Likert score greater than 3.0.

## Data Results and Analysis

Of the 104 skills listed in the round 2 questionnaire, agreement consensus was reached for 73 skills with average Likert scores $\geq$ 3.0 and average deviation $<$ 1.0 by both manager and technician groups (Table 1); the other thirty-one skills did not have agreement consensus with average Likert scores $<$ 3.0 or average deviation $\geq$ 1.0 for either manager or technician group (Table 2). Table 3 shows the 35 FET technical skills that are considered key, having a strong agreement consensus with average Likert scores $\geq$ 4.0 and average deviation $<$ 1.0 by both manager and technician groups; for these skills, the proficiency levels are shown ranging from 2.0 (limited experience) to 3.45 (intermediate experience). Interestingly, managers achieved consensus on 82% (85/104) of the skills, whereas technicians achieved consensus on 96% (100/104) of the skills.

Most of the skills lacking consensus among technicians also lacked consensus among managers (Table 2). A Mann-Whitney U test was used to determine that there are no significant differences between overall manager and technician agreement levels, $U = 6{,}507$, $z = .250$, $p = .802$. The participants strongly agreed (4.24 average Likert score, with an average deviation of 0.52) that the technical skills listed in the structured questionnaire represent the minimum expectations for FETs in an average sized acute-care facility; this result suggests that the list of FET technical skills was comprehensive and that the skills can be used to support an educational framework, even though the details of each FET technical skill should be considered. The following subsections discuss the results, organized by division.

### Wood, Plastic, Composite

In the wood, plastic, composite division, agreement consensus was achieved for the skills of installing hinges, brackets, mounting hardware, cabinets, shelves, and

**TABLE 1.—**Healthcare FET technical skills with agreement consensus

| Division | Skill | Mgr. avg. score | Mgr. avg. deviation | Tech. avg. score | Tech. avg. deviation |
|---|---|---|---|---|---|
| Wood, plastic, composite | Install hinges, brackets, and mounting hardware | 4.50 | 0.58 | 4.56 | 0.49 |
| Wood, plastic, composite | Install cabinets, shelves, and countertops | 4.25 | 0.75 | 4.00 | 0.44 |
| Wood, plastic, composite | Frame metal walls | 3.27 | 0.84 | 3.47 | 0.84 |
| Flooring | Install cove base | 4.42 | 0.78 | 4.65 | 0.42 |
| Flooring | Install and repair vinyl/VCT flooring | 3.67 | 0.67 | 3.82 | 0.78 |
| Flooring | Install and repair carpet | 3.42 | 0.94 | 3.41 | 0.73 |
| Flooring | Install and repair rubber flooring | 3.08 | 0.93 | 3.53 | 0.89 |
| Thermal and moisture protection | Inspect and repair smoke and fire walls | 4.75 | 0.38 | 4.53 | 0.46 |
| Thermal and moisture protection | Seal interior/exterior joints in doors, windows, floors, and walls | 3.81 | 0.57 | 4.00 | 0.58 |
| Thermal and moisture protection | Seal interior/exterior concrete joints and cracks | 3.58 | 0.89 | 4.00 | 0.47 |
| Doors | Inspect doors and frames for life-safety requirements | 4.58 | 0.49 | 4.59 | 0.50 |
| Doors | Adjust hydraulic closures, including back check, closing and latch speed, and spring adjustment | 4.67 | 0.44 | 4.29 | 0.62 |
| Doors | Install, repair, and inspect door hardware, including locks, keypads, dead latches, and strike plates | 4.42 | 0.49 | 4.47 | 0.50 |
| Doors | Install door casing and trim | 3.58 | 0.82 | 4.06 | 0.55 |
| Doors | Inspect shafts for life-safety requirements | 4.00 | 0.50 | 3.65 | 0.78 |
| Doors | Repair chute safety interlocks and switches | 3.08 | 0.76 | 3.59 | 0.84 |
| Plaster and gypsum board | Install acoustic ceiling tile | 4.58 | 0.56 | 4.59 | 0.46 |
| Plaster and gypsum board | Install and repair drywall | 4.33 | 0.78 | 4.47 | 0.50 |
| Plaster and gypsum board | Paint | 4.00 | 0.83 | 4.29 | 0.58 |
| Commercial equipment | Repair office furniture, including chairs, desks, and tables | 3.83 | 0.61 | 4.35 | 0.53 |
| Commercial equipment | Troubleshoot and repair ice machines | 3.67 | 0.89 | 3.82 | 0.67 |
| Commercial equipment | Troubleshoot and repair steamers | 3.00 | 0.67 | 3.06 | 0.72 |
| Mechanical support | Identify fasteners and appropriate use of nuts, bolts, screws, washers, rivets, anchors, inserts, and retaining rings | 4.67 | 0.44 | 4.59 | 0.48 |
| Mechanical support | Change vehicle tires, including on work trucks and golf carts | 4.50 | 0.50 | 3.71 | 0.66 |
| Mechanical support | Inspect mechanical equipment via vision, vibration, and sound | 4.17 | 0.69 | 4.24 | 0.54 |
| Mechanical support | Replace mechanical equipment filters and fluids | 4.00 | 0.83 | 4.12 | 0.52 |
| Mechanical support | Interpret MEP documents, including schematics, blueprints, specifications, and manuals | 3.58 | 0.89 | 3.82 | 0.64 |
| Fire support | Reset pull stations/system in case of code red | 4.42 | 0.49 | 4.12 | 0.50 |
| Fire support | Disassemble mounting brackets for ceiling tile replacement | 4.00 | 0.50 | 4.24 | 0.48 |
| Fire support | Clean sprinkler heads, smoke heads, and heat detectors | 4.17 | 0.56 | 4.06 | 0.44 |
| Fire support | Enable/disable smoke detectors | 4.17 | 0.42 | 3.76 | 0.79 |
| Fire support | Inspect water-based systems, including piping and fittings | 4.00 | 0.67 | 3.76 | 0.69 |
| Fire support | Perform elevator recall tests | 3.92 | 0.81 | 3.35 | 0.91 |
| Fire support | Inspect fire and smoke dampers | 3.67 | 0.83 | 3.35 | 0.84 |
| Plumbing | Repair and replace fixtures, including faucets, toilets, urinals, and flushometers | 4.75 | 0.38 | 4.63 | 0.43 |
| Plumbing | Clean sinks and grease traps | 4.75 | 0.38 | 4.06 | 0.62 |
| Plumbing | Auger drains | 4.50 | 0.50 | 4.47 | 0.61 |
| Plumbing | Shut off water by room/unit | 4.50 | 0.50 | 4.24 | 0.75 |
| Plumbing | Identify piping materials and appropriate use of copper, PVC, cast iron, PEX, and galvanized materials | 4.08 | 0.61 | 4.12 | 0.52 |
| Plumbing | Repair piping connections, including fit valves and couplings | 4.00 | 0.50 | 3.71 | 0.89 |
| Plumbing | Handle and store process gas and liquid, including through using medical gas cylinders | 4.00 | 0.33 | 3.76 | 0.72 |
| Plumbing | Repair piping angles and supports | 3.64 | 0.76 | 3.59 | 0.91 |
| Plumbing | Maintain and clean vacuum system bags | 3.60 | 0.76 | 3.47 | 0.73 |
| Plumbing | Thread piping through using tap and die | 3.58 | 0.79 | 3.59 | 0.84 |
| Plumbing | Repair water, air, and sewer piping | 3.50 | 0.69 | 3.55 | 0.97 |
| Plumbing | Solder and braze | 3.46 | 0.76 | 3.59 | 0.91 |
| Plumbing | Install and repair air piping | 3.33 | 0.78 | 3.41 | 0.96 |
| Plumbing | Inspect and repair soft water system | 3.25 | 0.75 | 3.29 | 0.70 |
| Plumbing | Inspect and repair reverse osmosis system | 3.17 | 0.86 | 3.29 | 0.82 |
| Plumbing | Weld (arc and oxygen/acetylene) | 3.13 | 0.82 | 3.38 | 0.75 |
| HVAC and automation | Use computerized maintenance management system and associated technology | 4.42 | 0.49 | 3.94 | 0.71 |

**TABLE 1.**—Continued.

| Division | Skill | Mgr. avg. score | Mgr. avg. deviation | Tech. avg. score | Tech. avg. deviation |
|---|---|---|---|---|---|
| HVAC and automation | Inspect and repair insulation | 4.00 | 0.50 | 3.71 | 0.42 |
| HVAC and automation | Inspect room ventilation, airflow, and pressure | 4.00 | 0.83 | 3.71 | 0.42 |
| HVAC and automation | Adjust air controls, including pneumatic and electronic | 3.75 | 0.71 | 3.35 | 0.97 |
| Electrical | Identify and repair light fixtures | 4.50 | 0.50 | 4.47 | 0.56 |
| Electrical | Replace lights and fluorescent ballasts | 4.50 | 0.50 | 4.31 | 0.69 |
| Electrical | Find current, voltage, and resistance (Ohm's law) using a digital multimeter | 4.33 | 0.56 | 4.24 | 0.58 |
| Electrical | Repair and maintain medium- and low-voltage electrical outlets | 4.17 | 0.42 | 3.82 | 0.87 |
| Electrical | Repair and maintain medium- and low-voltage electrical circuit wiring | 4.17 | 0.42 | 3.82 | 0.84 |
| Electrical | Repair and maintain medium- and low-voltage electrical switches | 3.92 | 0.63 | 3.76 | 0.84 |
| Electrical | Repair and maintain medium- and low-voltage electrical motors | 3.58 | 0.82 | 3.41 | 0.97 |
| Electrical | Repair and maintain medium- and low-voltage electrical breakers | 3.50 | 0.92 | 3.65 | 0.93 |
| Electrical | Repair and maintain medium- and low-voltage electrical relays | 3.27 | 0.84 | 3.24 | 0.91 |
| Electrical | Set up bed plugs for nurse call system | 3.25 | 0.92 | 3.29 | 0.84 |
| Safety and compliance | Recognize when a job is above the FET's skill level and requires a tradesperson with specialized training | 4.92 | 0.15 | 4.94 | 0.11 |
| Safety and compliance | Demonstrate safe and appropriate use of power tools, including drills, saws, grinders, welders, plasma cutters, and tee pullers | 4.92 | 0.15 | 4.82 | 0.29 |
| Safety and compliance | Demonstrate ladder safety | 4.92 | 0.15 | 4.76 | 0.29 |
| Safety and compliance | Demonstrate infection-control procedures, including "above ceiling" and infection control risk assessment | 4.92 | 0.15 | 4.76 | 0.29 |
| Safety and compliance | Demonstrate safe and appropriate use of hand tools, including wrenches, screw drivers, pliers, hammers, and saws | 4.92 | 0.15 | 4.76 | 0.29 |
| Safety and compliance | Demonstrate fire safety | 4.83 | 0.28 | 4.76 | 0.29 |
| Safety and compliance | Demonstrate compliance with OSHA regulations | 4.92 | 0.15 | 4.71 | 0.36 |
| Safety and compliance | Demonstrate electrical safety, including avoiding ARC flashes | 4.67 | 0.50 | 4.65 | 0.42 |
| Safety and compliance | Demonstrate appropriate bio hazard cleanup and disposal | 4.58 | 0.56 | 4.59 | 0.50 |

countertops (Table 1). These skills are also considered key skills for healthcare FETs (Table 3). The skill of framing wood walls did not have agreement consensus (Table 2).

**Concrete**

In the concrete division, agreement consensus was not achieved for either of the skills: building concrete forms and mixing, pouring, and finishing concrete (Table 2).

**Flooring**

In the flooring division, consensus agreement was achieved for the skill of installing and repairing cove base, vinyl/VTC, carpet, and rubber flooring (Table 1). Of these skills, only installing cove base is considered a key skill for healthcare FETs (Table 3). Agreement consensus was not achieved for the skill of installing and repairing epoxy and terrazzo flooring (Table 2).

**Thermal and Moisture Protection**

In the thermal and moisture protection division, agreement consensus was achieved for the skills of inspecting and repairing smoke walls; sealing interior and exterior joints in doors, windows, floors, and walls; and sealing interior and exterior joints and cracks in concrete (Table 1). Of these skills, inspecting and repairing smoke and fire walls is considered a key skill for healthcare FETs (Table 3).

**Doors**

In the doors division, agreement consensus was achieved for the skills of inspecting doors, frames, and shafts for life-safety requirements; adjusting hydraulic closures; installing, repairing, and inspecting door hardware; installing door casing and trim; and repairing chute safety interlocks and switches (Table 1). Three of these skills—inspecting doors and frames for life-safety requirements, adjusting hydraulic closures, and installing, repairing, and inspecting door hardware—are considered key for healthcare FETs (Table 3). Installing and repairing doors and frames did not have agreement consensus (Table 2).

**Plaster and Gypsum Board**

In the plaster and gypsum board division, agreement consensus was achieved for installing acoustic ceiling tile,

**TABLE 2.—**Healthcare FET technical skills without agreement consensus or with disagreement consensus

| Division | Skill | Mgr. avg. score | Mgr. avg. deviation | Tech. avg. score | Tech. avg. deviation |
|---|---|---|---|---|---|
| Wood, plastic, composite | Frame wood walls | 2.58 | 1.08 | 3.18 | 0.78 |
| Concrete | Build concrete forms | 2.83 | 1.17 | 2.88 | 0.47 |
| Concrete | Mix, pour, and finish concrete | 3.00 | 1.17 | 2.94 | 0.66 |
| Flooring | Install and repair epoxy flooring | 2.67 | 1.17 | 2.88 | 0.47 |
| Flooring | Repair terrazzo flooring | 2.33 | 0.94 | 2.94 | 0.66 |
| Doors | Install and repair doors and frames | 3.58 | 1.15 | 3.94 | 0.59 |
| Plaster and gypsum board | Texture drywall, including via skip trowel technique | 3.42 | 1.18 | 3.82 | 0.75 |
| Plaster and gypsum board | Install and repair wallpaper | 3.17 | 1.06 | 3.12 | 0.53 |
| Commercial equipment | Troubleshoot and repair refrigerators | 2.75 | 0.75 | 3.18 | 0.86 |
| Commercial equipment | Troubleshoot and repair stoves | 2.83 | 0.83 | 3.18 | 0.53 |
| Commercial equipment | Troubleshoot and repair ovens | 2.75 | 0.75 | 3.12 | 0.60 |
| Commercial equipment | Troubleshoot and repair microwaves | 2.50 | 0.83 | 2.71 | 0.82 |
| Commercial equipment | Troubleshoot and repair coffee makers | 2.42 | 0.65 | 2.82 | 0.60 |
| Commercial equipment | Troubleshoot and repair televisions, including speakers and remotes | 3.17 | 1.00 | 3.29 | 0.77 |
| Mechanical support | Repair and maintain belts on power transmission equipment | 3.75 | 1.17 | 3.94 | 0.68 |
| Mechanical support | Repair and maintain sprockets on power transmission equipment | 3.25 | 1.25 | 3.35 | 0.63 |
| Mechanical support | Repair and maintain gear boxes on power transmission equipment | 2.58 | 1.01 | 2.82 | 0.57 |
| Mechanical support | Repair and maintain pulleys on power transmission equipment | 2.92 | 1.08 | 3.24 | 0.70 |
| Mechanical support | Repair and maintain mechanical equipment bearings | 3.17 | 1.14 | 3.06 | 0.83 |
| Fire support | Inspect dry pipe sprinkler system | 2.75 | 0.79 | 3.44 | 0.74 |
| Plumbing | Install and repair steam piping | 2.33 | 1.06 | 2.88 | 0.66 |
| Plumbing | Install and repair condensate piping | 2.92 | 0.93 | 3.06 | 0.69 |
| Plumbing | Replace medical gas outlets and connect hoses | 3.58 | 1.06 | 3.41 | 0.91 |
| HVAC and automation | Inspect steam traps | 2.83 | 1.17 | 2.88 | 0.82 |
| HVAC and automation | Place HVAC system in standby/ramp-down mode, and demonstrate impact on other areas fed by the system | 3.33 | 1.44 | 3.00 | 1.09 |
| HVAC and automation | Monitor, reset, and adjust setting responses, including two position, floating, proportional, and PID | 3.08 | 1.10 | 2.88 | 0.78 |
| HVAC and automation | Control sensors and loops | 2.92 | 0.94 | 2.92 | 0.80 |
| Electrical | Repair and maintain medium- and low-voltage transformers | 3.00 | 0.91 | 3.12 | 1.02 |
| Electrical | Repair and maintain medium- and low-voltage fuses | 3.92 | 0.63 | 3.59 | 1.04 |
| Electrical | Troubleshoot and repair resistive electrical circuits, including series, parallel, and combination | 3.55 | 0.58 | 3.29 | 1.02 |
| Electrical | Troubleshoot and correct power factor | 2.64 | 1.01 | 3.19 | 0.81 |

installing and repairing drywall, and painting (Table 1). These skills are considered key for healthcare FETs (Table 3). Agreement consensus was not achieved for the skills of texturing drywall and installing and repairing wallpaper (Table 2).

### Commercial Equipment

In the commercial equipment division, agreement consensus was achieved for the skills of repairing office furniture and troubleshooting and repairing ice machines and steamers (Table 1). Agreement consensus was not achieved for the skills of troubleshooting and repairing refrigerators, stoves, ovens, microwaves, and coffee makers (Table 2).

### Mechanical Support

In the mechanical support division, agreement consensus was achieved for the skills of identifying fasteners and appropriate use of nuts, bolts, screws, washers, rivets, anchors, inserts, and retaining rings; inspecting and replacing mechanical equipment; changing vehicle tires (Table 1). The first two skills are also considered key healthcare FET skills (Table 3). Agreement consensus was not achieved for the skills of repairing and maintaining mechanical equipment bearings and repairing and maintaining belts, sprockets, gear boxes, and pulleys on power transmission equipment (Table 2). Interestingly, the technician group achieved agreement consensus for all of these skills, with the exception of repairing and maintaining gear boxes.

### Fire Support

In the fire support division, agreement consensus was achieved for the skills of resetting pull stations in case of code red, disassembling mounting brackets, cleaning sprinkler and smoke heads and heat detectors, enabling and disabling smoke detectors, inspecting water-based systems, performing elevator recall tests, and inspecting fire and smoke dampers (Table 1). Of these skills, resetting pull stations, disassembling mounting brackets, and cleaning sprinkler and smoke heads and heat detectors are considered key skills for healthcare FETs (Table 3). Agreement consensus was not achieved for the skill of inspecting dry pipe sprinkler (Table 2).

**TABLE 3.—**Key healthcare FET technical skills, with proficiency levels

| Division | Skill | Proficiency level |
|---|---|---|
| Wood, plastic, composite | Install hinges, brackets, and mounting hardware | Intermediate experience |
| Wood, plastic, composite | Install cabinets, shelves, and countertops | Limited experience |
| Flooring | Install cove base | Intermediate experience |
| Thermal and moisture protection | Inspect and repair smoke and fire walls | Limited experience |
| Doors | Inspect doors and frames for life-safety requirements | Limited experience |
| Doors | Adjust hydraulic closures, including back check, closing and latch speed, and spring adjustment | Intermediate experience |
| Doors | Install, repair, and inspect door hardware, including locks, keypads, dead latches, and strike plates | Limited experience |
| Plaster and gypsum board | Install acoustic ceiling tile | Intermediate experience |
| Plaster and gypsum board | Install and repair drywall | Limited experience |
| Plaster and gypsum board | Paint | Intermediate experience |
| Commercial equipment | Repair office furniture, including chairs, desks, and tables | Limited experience |
| Mechanical support | Identify fasteners and appropriate use of nuts, bolts, screws, washers, rivets, anchors, inserts, and retaining rings | Intermediate experience |
| Mechanical support | Inspect mechanical equipment using vision, vibration, and sound | Limited experience |
| Mechanical support | Replace mechanical equipment filters and fluids | Limited experience |
| Mechanical support | Change vehicle tires, including on work trucks and golf carts | Limited experience |
| Fire support | Reset pull stations/system in case of code red | Limited experience |
| Fire support | Disassemble mounting brackets for ceiling tile replacement | Limited experience |
| Fire support | Clean sprinkler heads, smoke heads, and heat detectors | Limited experience |
| Plumbing | Repair and replace fixtures, including faucets, toilets, urinals, and flushometers | Limited experience |
| Plumbing | Auger drains | Limited experience |
| Plumbing | Shut off water by room/unit | Intermediate experience |
| Plumbing | Clean sinks and grease traps | Limited experience |
| Plumbing | Identify piping materials and appropriate use of copper, PVC, cast iron, PEX, and galvanized materials | Limited experience |
| Electrical | Identify and repair light fixtures | Limited experience |
| Electrical | Replace lights and fluorescent ballasts | Limited experience |
| Electrical | Find current, voltage, and resistance (Ohm's law) using a digital multimeter | Limited experience |
| Safety and compliance | Recognize when a job is above the technician's skill level and requires a tradesperson with specialized training | Intermediate experience |
| Safety and compliance | Demonstrate safe and appropriate use of power tools, including drills, saws, grinders, welders, plasma cutters, and tee pullers | Intermediate experience |
| Safety and compliance | Demonstrate ladder safety | Intermediate experience |
| Safety and compliance | Demonstrate infection-control procedures, including "above ceiling" and infection control risk assessment | Intermediate experience |
| Safety and compliance | Demonstrate safe and appropriate use of hand tools, including wrenches, screw drivers, pliers, hammers, and saws | Intermediate experience |
| Safety and compliance | Demonstrate fire safety | Intermediate experience |
| Safety and compliance | Demonstrate compliance with OSHA regulations | Intermediate experience |
| Safety and compliance | Demonstrate electrical safety, including avoiding ARC flashes | Intermediate experience |
| Safety and compliance | Demonstrate appropriate bio hazard cleanup and disposal | Intermediate experience |

## Plumbing

In the plumbing division, agreement consensus was achieved for the skills of repairing and replacing fixtures, cleaning sinks and grease traps, augering drains, shutting off water, identifying piping materials and their appropriate use, repairing piping connections, handling and storing process gasses and liquids, repairing piping angles and supports, maintaining and cleaning vacuum system bags, threading piping through using taps and dies, installing and repairing piping (water, air, sewer), soldering and brazing, inspecting and repairing soft water systems, inspecting and repairing reverse osmosis systems, and welding (Table 1). Of these skills, the ones that are considered key for healthcare FETs are repairing and replacing fixtures, cleaning sinks and grease traps, augering drains, shutting off water, identifying piping materials and their appropriate use (Table 3). Agreement consensus was not achieved for the skills of installing and repairing steam piping, installing and repairing condensate piping, and replacing medical gas outlets and connect hoses (Table 2).

## HVAC and Automation

In the HVAC and automation division, agreement consensus was achieved for the skills of using computerized maintenance management systems and associated technology; inspecting and repairing insulation; inspecting and repairing insulation; inspecting room ventilation, airflow, and pressure; and adjusting air controls (Table 1). Agreement consensus was not achieved for the skills of inspecting steam traps; placing HVAC systems in standby or ramp-down mode; monitoring, resetting, and adjusting

setting responses; and controlling sensors and loops (Table 2).

**Electrical**

In the electrical division, agreement consensus was achieved for the skills of identifying and repairing light fixtures; replacing lights and fluorescent ballasts; finding current, voltage, and resistance (Ohm's law) using a digital millimeter; and repairing and maintaining medium- and low-voltage electrical outlets, circuit wiring, switches, motors, breakers, and relays (Table 1). Of these skills, the ones considered key for healthcare FETs are identifying and repairing light fixtures; replacing lights and fluorescent ballasts; and finding current, voltage, and resistance using a digital millimeter (Table 3). Agreement consensus was not achieved for the skills of repairing and maintaining medium- and low-voltage transformers and fuses, troubleshooting and repairing resistive electrical circuits, and troubleshooting and correcting power factor problems; (Table 2).

**Safety and Compliance**

In the safety and compliance division, agreement consensus was achieved for the skills of recognizing when a job is above the technician's skill level and requires a tradesperson with specialized training, demonstrating safe and appropriate use of tools, demonstrating ladder safety, demonstrating infection control procedures, demonstrating fire safety, demonstrating compliance with OSHA regulations, demonstrating electrical safety, and demonstrating appropriate bio hazard cleanup and disposal (Table 1). All skills in this division are considered key for healthcare FETs (Table 3).

## Conclusion

This research contributes to the limited body of knowledge regarding healthcare FET skills and capabilities. The study used the Delphi method and absolute deviation analysis to identify technical skills that healthcare FETs are expected to have in the areas of wood, plastic, and composite; flooring; doors; plaster and gypsum board; mechanical support; fire support; plumbing; electrical; and safety and compliance. The study also identified the proficiency level expected for each of the technical skills. A total of 104 skills were identified, and the managers and technicians reached agreement consensus on 73 of the skills. Of these 73 skills, 35 were deemed key with strong agreement consensus.

Successfully recruiting, training, and maintaining a competent FET workforce is essential but challenging for healthcare organizations, in part because of the lack of formal education programs and an unclear path of entry into the profession. The results of this research are valuable in that they can be used to develop needed training of the FET workforce. Trainers can use this research to assist with curriculum development and skill prioritization. Healthcare organizations can use this research to assess their current capabilities across staff and begin to develop strategic programs in response to the challenges of attracting and retaining FETs.

Future research is needed in the area of healthcare FET skills and capabilities because the current body of knowledge is limited. This research addressed FETs; other types of jobs need to be examined to move toward developing a more complete understanding of the skills and capabilities necessary for the spectrum of the facility engineering workforce (from technical to managerial) to address attrition, recruitment, retention, and succession challenges. Further, after the skills identified in this study are used to develop FET training, research needs to examine the effectiveness of this training in closing gaps in the workforce's skills and meeting organizations' strategic facility workforce objectives.

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