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SWECOM: the Software Engineering Competency Model

SWECAT: the Software Engineering Competency Assessment Tool

presented by

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Presentation Agenda

SWECOM: the Software Engineering Competency Model

- SWECOM development process
- Attributes of a Profession
- Elements of SWECOM
- SWECOM Technical Skill Areas
- SWECOM Competency Levels
- Ways of using SWECOM



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Presentation Agenda (2)

SWECAT

- The role of SWECAT
- Some examples
- Current status



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SWECOM

- Developed by a team of six CS-PAB-SSE committee members
- Reviewed by SMEs and at-large reviewers
- Reviews adjudicated and revisions made
- Approved by the IEEE-CS BOG
- Free downloads available at:

<http://www.computer.org/web/peb/swecom>



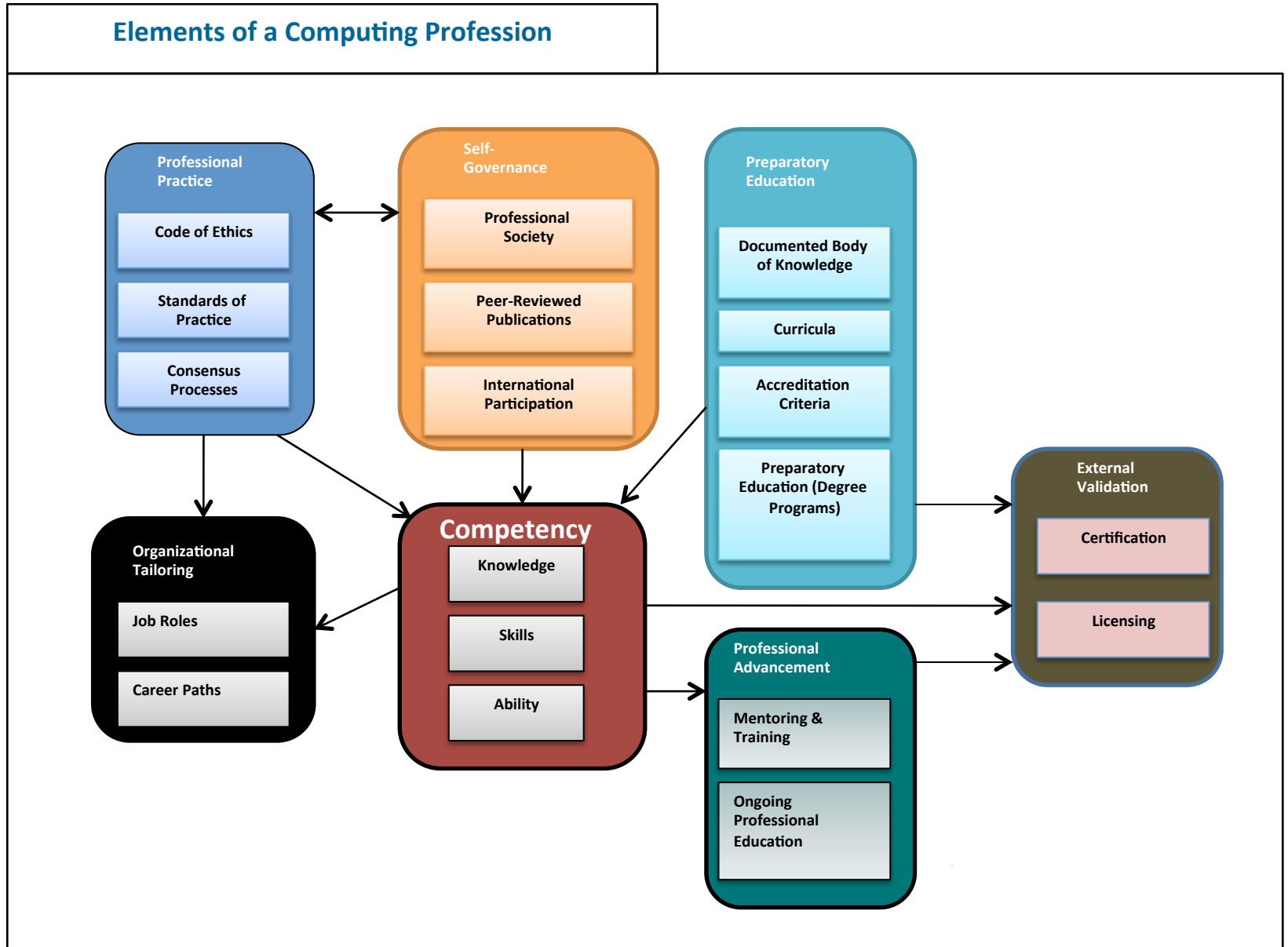
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The SWECOM Team

- Dick Fairley, S2EA, Team Leader
- Mark Ardis, Stevens Institute
- Kate Guillemette, IEEE Computer Society
- Thomas Hilburn, Embry Riddle University
- Ken Nidiffer, Software Engineering Institute
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Elements of a profession	Software engineering artifacts
Professional Society	IEEE Computer Society
Code of Ethics and Professional Practice	IEEE- ACM Code of Ethics and Professional Practice
Peer-reviewed publications	Transactions on Software Engineering International Conference on Software Engineering
Consensus Processes	IEEE Software Engineering Standards based on IEEE Standard 12207
Body of Knowledge	SWEBOK: Guide to the Software Engineering Body of Knowledge
Model Curricula	SE2014 and GswE 2009
Accredited education programs	ABET accredited software engineering programs
<i>Competency Model</i>	<i>SWECOM</i>
Certification and Licensure	Computer Society certifications NCEES professional engineer license



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Competency: Knowledge, Skill, and Ability

- Knowledge: what one knows about
- Skill: what one knows how do
- Ability: personal traits need to competently perform work activities
- A competent person has the knowledge, skills, and ability to perform work activities at a given competency level
- SWECOM includes five competency levels for each of 13 software engineering skill areas



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SWECOM knowledge sources

- The Guide to the Software Engineering Body of Knowledge
SWEBOK: <http://www.computer.org/web/swebok/v3-guide>)
- SwE related disciplines in SWEBOK
- ISO/IEC/IEEE Standard 12207 (software engineering processes)
- Other IEEE software engineering standards
- Textbooks and Curricula

See the References section of SWECOM for a list of 59 knowledge sources compiled from the references cited in the 13 skill areas



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Scope of SWECOM

- SWECOM includes
 - cognitive attributes
 - behavioral attributes and skills
 - technical skill areas, skills, and activities
 - extensive references
- SWECOM does not include
 - project management skills related to scheduling, budgeting, and resource management
 - industry-sector technical skills
 - ✓ e.g., embedded systems, IT, or applications
 - domain-specific skills
 - ✓ e.g., health sciences, communication, automotive domains



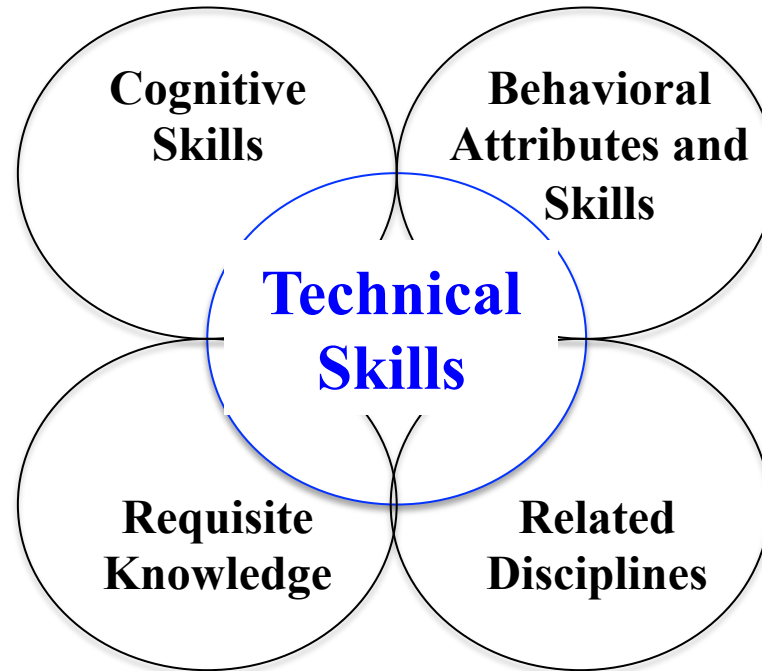
SWECOM TOC

- | | |
|---|---|
| <ol style="list-style-type: none">1. Introduction2. SWECOM and the US IT Competency Model3. The Elements of SWECOM4. SWECOM Technical Skills5. SWECOM Competency Levels6. Employer and Individual Gap Analysis7. SWECOM Validation8. Acknowledgements9. References10. Glossary of Terms11. Software Requirements Skill Area12. Software Design Skill Area13. Software Construction Skill Area14. Software Testing Skill Area15. Software Sustainment Skill Area | <ol style="list-style-type: none">16. Software Process and Life Cycle Skill Area17. Software Systems Engineering Skill Area18. Software Quality Skill Area19. Software Security Skill Area20. Software Safety Skill Area21. Software Configuration Management Skill Area22. Software Measurement Skill Area23. Human-Computer Interaction Skill Area24. Appendix A: Contributors25. Appendix B: SWECOM Intended Audiences26. Appendix C: SWECOM Use Cases27. Appendix D: Gap Analysis Worksheets |
|---|---|



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Elements of SWECOM



Only the Technical Skills are rated by competency level



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Related Disciplines

Related disciplines include, but are not limited to:

- Computer Engineering,
- Computer Science,
- General Management,
- Mathematics,
- Project Management,
- Quality Management, and
- Systems Engineering.

These are the related disciplines in SWEBOK



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SWECOM Cognitive Skills

- Cognitive skills apply across all skill areas, skills, and activities of SWECOM; they include but are not limited to:
 - reasoning skills
 - analytical skills
 - problem-solving skills
 - innovation skills



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SWECOM Behavioral Attributes and Skills

- Include but are not limited to:
 - aptitude
 - enthusiasm
 - initiative
 - work ethic
 - willingness
 - trustworthiness
 - cultural sensitivity
 - communication skills
 - team participation skills
 - technical leadership skills



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Skill Areas, Skill Categories, and Activities

- A *skill area* is a way of naming and grouping related skills
 - e.g., requirements engineering
- A *skill category* is a way of naming and grouping related activities within a skill area
 - e.g., requirements elicitation
- *Activities* are units of work that constitute a skill category
 - e.g., requirements elicitation activities: observation, interviews, prototyping, . . .



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Tables Axx

Table A11	
Software Requirements Skill Categories	Software Requirements Activities
Software Requirements Elicitation	<ul style="list-style-type: none">• Identifies stakeholders for elicitation of requirements• Engages stakeholders in elicitation of requirements• Uses appropriate methods and tools to capture requirements• Negotiates conflicts among stakeholders during elicitation
Software Requirements Analysis	<ul style="list-style-type: none">• Uses appropriate domain analysis techniques• Performs analysis of requirements for feasibility and emergent properties
Software Requirements Specification	<ul style="list-style-type: none">• Uses appropriate notations for describing requirements
Software Verification and Validation	<ul style="list-style-type: none">• Checks requirements for accuracy, lack of ambiguity, completeness, consistency, traceability and other desired attributes• Constructs and analyzes prototypes• Negotiates conflicts among stakeholders during verification and validation
Software Requirements Process and Product Management	<ul style="list-style-type: none">• Uses appropriate methods for management of requirements, including configuration management



Tables Bxx

Table B11					
Skill Category	Activity Levels				
	Technician	Entry Level Practitioner	Experienced Practitioner	Technical Leader	Senior Software Engineer
Software Requirements Elicitation	1. Assists with preparation of surveys, questionnaires and other elicitation instruments (F/A)	1. Participates in preparing surveys, questionnaires and other elicitation instruments (P)	1. Leads in preparation of surveys, questionnaires and other elicitation instruments (L)	1. Selects appropriate methods to engage and communicate with stakeholders in requirements elicitation activities (L)	1. Creates new ways to engage and communicate with stakeholders, the management team, and developers in requirements elicitation activities (C)
			2. Assists in negotiating conflicts between stakeholders in requirements elicitation (A)	2. Negotiates conflicts between stakeholders in requirements elicitation (P/L)	



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Two Caveats

1. The order of listing skill areas, skill categories, and activities does not imply a life cycle sequencing of software development phases
2. Activities are not job roles
 - but can be grouped into job roles
 - for specific organizations
 - and specific projects



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SWECOM Competency Levels

- SWECOM includes five competency levels for software engineering technical activities:
 1. technician
 2. entry level practitioner
 3. practitioner
 4. technical leader
 5. senior software engineer
- Some activities do not include competencies at all five competency levels
 - e.g., no technician-level skills for selecting a software development process



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Characterization of Competency Levels

- **Technician:** an individual who is competent to *follow instructions* while performing an activity
- **Entry Level Practitioner:** an individual who is competent to *assist* in performing an activity or to perform activities *with some supervision*
- **Experienced practitioner:** an individual who is competent to perform an activity with *little or no supervision*
- **Technical Leader:** an individual who is competent to *lead and direct* participants in the performance of the activities in one or more skills or skill areas
- **Senior software engineer:** an individual who is competent to *create new, and modify existing* processes, procedures, methods, and tools for performing activities, groups of activities within one or more skills, and skills within skill areas



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Characterization of Competency Levels (2)

- An individual may have different competency levels for different activities in a skill category
- To be competent at a given competency level in a skill category requires competency in all activities in that skill category at that given competency level
- To be competent at a given competency level in a skill area requires competency in all skill categories in that skill area at that given competency level



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SWECOM Use Cases

- Appendix C of SWECOM includes use cases to illustrate how the following individuals might use SWECOM
 - HR to develop recruitment and training plans
 - HR and managers to screen job applicants
 - HR and managers to develop strategies and plans
 - to counsel new job-hires
 - individuals to assess competencies and prepare self-improvement plans
 - managers to evaluate and counsel individuals on career development planning
 - curriculum designers to develop skills-based training programs and academic curricula



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Skills-based curricula

- Reading down the columns of SWECOM provides a list of the skills that should be covered in skills-based training and education
 - At the level of the activities for each skill



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Skills assessment

SWECOM provides a basis for objective skills assessment

- Individuals can self-assess and identify areas for improvement
- Managers can help individuals prepare career plans
- Project managers can perform gap analysis
 - And acquire the needed skills
- HR managers can prepare recruitment and training plans



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Skills assessment worksheet

Staffing Gap Analysis Worksheet

Date Completed: [xxx]

Organizational Unit: [xxx]

Completed by: [names and titles of those completing the worksheet]

Competencies (from Tables A and B of the SWECOM Skill Areas)

	Have	Need	Gap	Level
Software Requirements Skills				
Software Requirements Elicitation				
Software Requirements Analysis				
Software Requirements Specification				
Software Requirements Verification and Validation				
Software Requirements Management				
Software Design Skills				
Software Design Fundamentals				
Software Design Strategies and Methods				
Software Architectural Design				
Software Design Quality Analysis and Evaluation				
Software Construction Skills				
Software Construction Planning				

Note: **Have**, **Need**, and **Gap** indicate the number of individuals at the indicated skill level



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Question

Q: how can we objectively determine what an individual can do on the job?



Mechanisms for assessing an individual's skills

Skills can be assessed by:

- Observation
- Peer reviews
- Performance evaluations
- Portfolios of work
- SWECAT
 - Software Engineering Competency Assessment Tool

SWECOM provides the basis for skills assessment



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SWECAT

- SWECAT is a tool to provide *assistance* in evaluating an individual's technical competencies in selected skill categories and skill areas

- On-the-job performance call cannot be fully evaluated by a competency exercise
- Because on-the-job performance requires:
 - Technical skills
 - Cognitive skills
 - Behavioral attributes



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SWECAT – a work in progress

Three research questions:

1. Can a skills-based exercise provide information useful in evaluating an individual's competencies in software engineering skill areas?
2. Can a skills-based exercise provide information to assist in differentiating skill levels?
for example, entry level practitioner versus experienced practitioner
3. Can skills-based training improve the competency level of an individual?
 - for example, an experience accelerator lab
(analogy: flight simulators improve pilots' skill levels)



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An approach and some examples

- Given a list of issues categories for a skill area such as requirements engineering
- And a list of requirements that contain issues
 - Some have no issues, some have one, and some have more than one
- Ask an individual to identify the issues and write a short statement about the nature of each issue
- Produce a report that compares the individual's answers to the “preferred” answers



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Requirements issues categories

- R1 Incorrect: the requirements is in error for this domain
- R2 Incomplete: there is not enough information to know if the requirement is OK or not
- R3 Inconsistent: two or more requirements disagree
- R4 Unclear: the meaning of the requirement is hard to understand
- R5 Ambiguous: a requirement can be interpreted in different ways
- R6 Missing Information: the context for a requirement is missing
- R7 Questionable Constraint: a requirement that “it must be this way” is questionable
- R8 Missing Constraint: is a necessary limitation needed?
- R9 Excessive Constraint: is this level of constraint necessary?
- R10 Extraneous Information: information that does not belong is this set of requirements



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An Example

A requirement statement:

Requirement #1. The DigitalHome programmable thermostat shall allow a user to monitor and control a home's temperature from almost any place using almost any web-enabled device.

Issue category(s):

Comment(s):

What do you think?



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The Preferred Answer

Requirement #1. The DigitalHome programmable thermostat shall allow a user to monitor and control a home's temperature from almost any place using almost any web-enabled device.

Issue category: R5 Ambiguous

Explanation: almost any place? Almost any web-enabled device? What places and web-enabled devices are excluded?

Issue category: R7 Questionable Constraint

Explanation: does "The" thermostat mean that a DigitalHome is limited to one thermostat? If more than one is there a design constraint on the maximum number of thermostats?



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Requirement #2

Requirement #2. The DigitalHome system shall permit setting of each thermostat's temperature to between 60 ° F and 80 ° F.

Issue category(s):

Comment(s):

What do you think?



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Requirement #2

Requirement #2. The DigitalHome system shall permit setting of each thermostat's on and off temperatures in a range between 60 ° F and 80 ° F.

Issue category: R7 Questionable Constraint.

Comment: Why is the range limited to 60 ° F to 80 ° F?



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Requirement #3

Requirement #3. A thermostat shall turn on the heating system when the temperature is $> 80^{\circ} \text{F}$.

Issue category(s):

Comment(s):

What do you think?



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Requirement #3

Requirement #3. A thermostat shall turn on the heating system when the sensed temperature is $> 80^{\circ} \text{F}$.

Issue category: R1 Incorrect

Comment: “ $>$ ” should be “ $<$ ” OR “on” should be “off”

Issue category: R7 Questionable Constraint.

Comment: why 80°F ? why not settable?

Issue category: R5 Ambiguous

Comment: What does this requirement mean?



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Requirement #4

- Requirement #4. Thermostats shall be placed as desired in areas where the air temperature is to be controlled.
- Issue category(s):
- Comment(s):
- What do you think?



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Requirement #4

- Requirement #4. Single thermostats shall be placed as desired in areas where the air temperature is to be controlled.

- Issue category: none?

R9 Extraneous information?

- Comment: is this requirement OK or extraneous?



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Requirement #5

- Requirement #5. For each thermostat, up to four different settings per day for every day of the week can be scheduled.
- Issue category: R5 Ambiguous.
- Comment: Does every day of the week mean four different settings for each of the seven days in a week or four different settings that apply to all of the seven days in a week?



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A preliminary result

- An exercise using a list of 10 requirements for the DigitalHome system has been administered to students in two graduate-level software requirements engineering classes
- Student with more experience clearly perform better than students with less experience
- Observations:
 - students with less experience “reach” for issues that aren’t there
 - Students with more experience tend to make assumptions that may or may not be valid



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The most important result

The exercise has resulted in some deep and interesting discussions



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To Repeat

- SWECAT is a work in progress
- It appears that exercises can provide assistance in evaluating an individual's areas of competency
 - At different competency levels



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SWECOM and SWECAT Status

- SWECOM has been published by the IEEE Computer Society
 - <http://www.computer.org/web/peb/swecom>
 - free downloads world-wide
- The requirements for SWECAT have been written and reviewed
- A Learning Management System for implementation of SWECAT is being identified
- A prototype SWECAT tool will be constructed to investigate the 3 research questions



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SWECOM Summary (1)

- SWECOM development process
- Attributes of a Profession
- Elements of SWECOM
- SWECOM Technical Skill Areas
- SWECOM Competency Levels
- Ways of using SWECOM



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SWECAT Summary (2)

- The role of SWECAT
- Some examples
- Current status



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- Questions?
- Comments?