Professionalizing the Practice of Software Engineering

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The MITRE Corporation
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- Ann Sobel, Curriculum
- Steve Tockey, Certification
- Janet Wilson, SWEBOK Guide
Software Engineering is a Profession

The Future Of Software Engineering

- Technical
  - The dominance of component-based software engineering
  - The codification of reference architectures
  - The evolution of virtual teams
  - The acceptance of well-defined processes
  - The creation of frictionless surfaces
  - The rise of software engineering as a profession

- Social
  - The impact of legal issues
  - The scarcity of skilled workers
  - The growth of non-programmers

From Grady Booch, “The Future of Software”

The Growth Of Non-Programmers

“Software Engineering” will have no future unless we accept the fact that only a small fraction of software developers are qualified to be called “Software Engineers” and agree on standards that distinguish those who are qualified from the rest of us.

David Parnas
Outline

• An “Engineering” Model of a Software Engineering Career
• Body of Knowledge
  – SWEBOK Update
• Professional Education
  – Curriculum
  – Accreditation
  – Graduate Curriculum project
• Professional Development
  – Certification
  – Training
  – Licensing initiative
• Professional Practice
  – Standards
  – Code of Ethics
An “Engineering” Model of a Software Engineering Career
Ten years ago, most of this did not exist for software engineering. It all exists now.
IEEE CS Support of the SWE Professional

- Initial professional education
- Skills Development
  - Body of knowledge: SWEBOK Guide
  - Professional Education: SE 2004 Curriculum, ABET Accreditation, Graduate Curriculum
  - Professional Development: CSDA, CSDP, Training, Licensing
  - Professional Practice: Standards, Code of Ethics

Adapted from Steve McConnell, *After the Gold Rush*, Microsoft Press

IEEE computer society
60th anniversary

SSTC 2009

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Body of Knowledge

2004 SWEBOK Guide
SWEBOK Guide Refresh
Software Engineering Body of Knowledge Project

- Promote a **consistent view of software engineering** worldwide
- Clarify the place of, and **set the boundary of**, software engineering with respect to other disciplines
- **Characterize the contents** of the Software Engineering Body of Knowledge - SWEBOK
- **Provide a topical access** to the SWEBOK
- **Provide a foundation** for curriculum development and individual certification and licensing material

The Body of Knowledge for software engineering already exists in the literature. The mission of the SWEBOK project is to provide an authoritative guide to the portion that is “generally accepted.”
## Types of Knowledge

<table>
<thead>
<tr>
<th>Specialized</th>
<th>Generally Accepted</th>
<th>Advanced and Research</th>
</tr>
</thead>
</table>

**Generally accepted:** “Applies to most projects most of the time and widespread consensus validates its value and effectiveness.” -- PMI

In terms of US education, we target the SWEBOK at bachelor’s degree plus four years of experience.
Ten Knowledge Areas

- Software Requirements
- Software Design
- Software Construction
- Software Testing
- Software Maintenance
- Software Configuration Management
- Software Eng. Management
- Software Eng. Tools & Methods
- Software Engineering Process
- Software Quality

Related Disciplines

- Computer Science
- Mathematics
- Project Management
- Computer Engineering
- Cognitive Sciences
- Human Factors
- Systems Engineering
- Management
- Management Science
Knowledge Area Description

Classification of Topics

Matrix of Topics & References

References

Topic Descriptions

Classification by Bloom’s Taxonomy

References to Related Disciplines

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There is substantial agreement on the scope of Software Engineering

SWEBOK, CSDP, and SE2004 each characterized the scope of software engineering.

Each followed its own consensus process.

The extent of agreement among the three is remarkable.

It is a powerful validation of the characterization.

Nevertheless, the minor differences should be resolved.
Plan for Refresh of SWEBOK Guide

• Broaden the contents to span the consensus achieved by:
  – 2004 SWEBOK Guide
  – SE 2004 curriculum
  – Original CSDP test specification
• Move toward a continuous update process
• Provide provisional “supplementary” KAs in emerging and specialty areas for comment and trial usage
  – Security
  – Measurement
• Lead editors
  – Alain Abran, École de technologie supérieure, Canada
  – Pierre Bourque, École de technologie supérieure, Canada
  – Juan Garbajosa, Universidad Politécnica de Madrid, Spain
  – Gargi Keeni, Tata Consultancy Services, India
  – Beijun Shen, Shanghai Jiaotong University, China
• Publication planned for 2010
• Will underlay professional development products of the Society
Planned Content of 2010 SWEBOK Guide

• Characterizing the Practice of Software Engineering
  – SW Requirements
  – SW Design
    • Human-Computer Interface Design
  – SW Construction
  – SW Testing
    • Human-Computer Interface Testing
  – SW Maintenance
  – SW CM
  – SW Eng Management
  – SW Eng Process
  – SW Eng Methods [changed name]
    • Cross-KA methodologies and their selection
    • [Distribute tools into other KAs]
  – SW Quality
  – SW Eng Professional Practice

• Required in Educating a Software Engineer
  – Computer Science Foundations
  – Mathematical Foundations
  – Engineering Foundations
  – Economic Foundations

• Related Disciplines
  – Computer Engineering
  – Computer Science
  – Mathematics
  – Management
  – Project Management
  – Quality Management
  – Software Ergonomics
  – System Engineering

• Supplementary (“trial-use”)
  – Measurement
  – Security
Take Away Items

• There is broad agreement on the body of knowledge for Software Engineering.

• Three different consensus mechanisms have reached nearly identical conclusions.

• The 2010 revision of the SWEBOK Guide will be broadened to deal with the small differences among the three.
Professional Education

Curriculum
Accreditation
Graduate Curriculum
IEEE-CS/ACM Computing Curricula Series

- Computer Science Volume – revised in 2008
- Software Engineering Volume – 2004
- Computer Engineering Volume – 2004
- Information Systems Volume – revised in 2009
- Information Technology Volume – 2008
SE 2004 Components

• Software Engineering Education Knowledge – What every SE graduate should know:
  – Computing Essentials (172 contact hours)
  – Mathematical and Engineering Fundamentals (89)
  – Professional Practice (35)
  – Software Modeling and Analysis (53)
  – Software Design (45)
  – Software Verification and Validation (42)
  – Software Evolution (10)
  – Software Process (13)
  – Software Quality (16)
  – Software Management (19)

• Curriculum – Suggestions for how it should be taught
Specialized Accreditation

• Distinct from “institutional accreditation”
• Focuses on particular aspects of an academic field of study, including engineering, nursing, law, or education, among others
• Some professions that are regulated by and dependent upon a state or national licensing board may require job applicants to have graduated from specific accredited academic programs that have specialized, professional, or programmatic accreditation status.
ABET does Computing Accreditation

• Computing Accreditation Commission
  – Computer Science
  – Software Engineering*
  – Information Science
  – Information Technology

• Engineering Accreditation Commission
  – Computer Engineering*
  – Electrical Engineering
  – Mechanical Engineering
  – Chemical Engineering
  – Civil Engineering …

* Computer Engineering and Software Engineering are Jointly Accredited.
ABET Accreditation

• Software Engineering and Computer Engineering are evaluated by ABET like any other engineering program
  – EAC General Criteria
  – Software Engineering Program Criteria
    • Curriculum must provide breadth and depth of engineering and computer science topics
    • Graduates must have the ability to:
      – analyze, design, verify, validate, implement, apply, and maintain software systems
      – the ability to appropriately apply discrete mathematics, probability and statistics, and relevant topics in computer science and supporting disciplines to complex software systems
      – and the ability to work in one or more significant application domains.

• There are currently 16 accredited SwE programs
Graduate Software Engineering Reference Curriculum (GSwERC)

- Led by Art Pyster, Stevens Institute
- Sponsored by DoD
- Participation by professional societies
- 3 Reference Curricula at Masters level
  - SW Engineering (with an appropriate amount of SE)
  - Systems Engineering (with an appropriate amount of SwE)
  - An interdisciplinary degree
Outcomes for GSwERC Grads

- Mastery of core body of knowledge
- Mastery of one application domain
- Deep mastery of one knowledge area
- Knowledge of ethics
- SE/SwE relationship
- Teamwork and leadership
- Trade-offs
- “Soft skills”
- Continued professional development
- Mastery of one technology
**Take-Away Items**

- There is a model curriculum (SE 2004) for an undergraduate degree in Software Engineering
  - Distinct from Computer Science, Computer Engineering, Information Systems, and Information Technology
- There will soon be a model curriculum (GSwERC) for a master’s degree in Software Engineering
- ABET accredits Software Engineering programs.
- As of October 2005, in the US, there are...
  - 32 bachelor’s level programs (15 accredited)
  - 53 master’s level programs
  - 4 PhD programs
  - Another 15 accredited bachelor’s programs in Canada.
Professional Development

Certification
Training
Licensing
What is Certification?

• **Formal recognition** of demonstrated proficiency within and comprehension of a specified body of knowledge at a point in time.

• It is **peer recognition** and not registration or licensure.
  – *Registration*: listing by and with a body of individuals or organizations that are certified
  – *Licensure*: authorization granted by government body for an individual or organization to practice a business or occupation

• Certification is **voluntary**.
Three Types of Certification

• **Training-related**
  – Completion of a set of courses
  – (This is sometimes called a “certificate” rather than a “certification”.)

• **Product-related**
  – Knowledge of a particular product or product line
  – e.g. MCSE, CNE

• **Professional**
  – Mastery of a long-lived set of principles and ethics fundamental to practice in a professional field
  – e.g. PMP, CSDP, CSQE, PHR
Basis for Professional Certifications

- Professional certifications are usually founded on professional society norms such as:
  - A specified Body of Knowledge: IEEE-CS Guide to the Software Engineering Body of Knowledge*
  - A set of professional practice standards: IEEE and international standards on software engineering
- ... and supported by appropriate training programs and materials.

* http://www.swebok.org
Computer Society Certifications

- CSDA: Designed to provide entry-level SW engineer with a baseline knowledge of fundamental development practices and a growth path to the CSDP and beyond.
- CSDP: Designed for mid-career SW engineers looking to advance in their field and confirm their knowledge of development practices.
% of Exam Questions in each KA

- CSDA
- CSDP
Depth of Knowledge in Exams

Skill Levels

Mastery
Leadership
Competency
Introductory

Notional Emphasis of CSDA Exam
Notional Emphasis of CSDP Exam

Knowledge Areas shared by SWEBOK and Certifications
(roughly ordered with suitability for university teaching toward the left and suitability for industrial experience toward the right)
Certification Requirements

• CSDA requirements - none
• CSDP requires both
  – Education qualifications
  – Experience qualifications
• Either requires passing appropriate exam
  – Computer-based
  – About 4 hours long
  – 180 questions
  – Multiple-choice questions selected from a pool of questions
  – Closed book, calculators provided
Exam Preparation Options

- CSDA e-Learning Course
  - 4 on-line modules covering 15 knowledge areas
  - 6 assessments: pre-test, post-test, 4 modules
  - CD or printed
- Sample exam questions
- SWEBOK Guide
- http://www.computer.org/csda/prep

- CSDP e-Learning Course
  - Covers 11 CSDP knowledge areas
  - CD or printed
- SWEBOK Guide
- Resource guide
- Book of sample questions
- http://www.computer.org/csdp/prep
A Path to Licensing

• A consortium of groups wants to provide a path to licensure for software engineers
  – IEEE subgroups, NSPE subgroups, Texas Board, NCEES

• Endorsements from ten state licensing agencies are required. So far:
  – Eight have endorsed
  – Additional one is rewriting their endorsement
  – Five others are considering
Licensing Software Engineers

• The process for licensing would be similar to any engineering profession:
  – Graduate from ABET-accredited curriculum
  – Pass the Fundamentals of Engineering exam
  – Four years of acceptable, supervised practice
  – Pass the Principles and Practices exam

• The consortium is proposing development of the P&P exam.
Would Everyone Need a License?

- Would all software engineers need to be licensed?
  - No, only those providing their services directly to the public.

- Would all software have to be developed by licensed software engineers?
  - No, only software that has an impact on the lives, property, economy, or security of people or the national defense.
Take-Away Items

• Licensing for software engineers is underway in Texas, British Columbia, Ontario, Canada and other countries.
• It is likely that many states in the US will offer a path to licensing by 2011.
• Currently, IEEE Computer Society offers professional certifications for entry-level and mid-level software professionals.
Professional Practice

Standards

Ethics
Harmonization of IEEE and ISO/IEC

- ISO/IEC JTC 1/SC 7 (software and systems engineering) has a large collection of standards.
  - Some of the key standards are difficult to use together.
- IEEE Software and Systems Engineering Standards Committee has a large collection of standards.
  - Some of the key standards are not completely consistent with the ISO/IEC standards.
- IEEE Computer Society and ISO/IEC JTC 1/SC 7 have entered into a program to “harmonize” their key standards to provide a shared, common framework, e.g.
  - A single shared set of processes.
  - A single shared vocabulary.
Intended Relationships of Key System and Software Engineering Life Cycle Process Standards

24748-1: Guide to Life Cycle Management

Other standards providing details of selected SW processes

12207: Life cycle processes for SW (And associated guide, 24748-3)

15289: Documentation

15288: Life cycle processes for systems (And associated guide, 24748-2)

Other standards providing details of selected system processes

16326: Project Mgmt

Revised 15939: Measurement

16085: Risk Mgmt

Interoperation

Common vocabulary. Common process description conventions

15026: Additional practices for higher assurance systems

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New Vocabulary Standard

- Systems and software engineering vocabulary
- Publicly available website [http://www.computer.org/sevocab/](http://www.computer.org/sevocab/)
- Provides access to 4100 authoritative definitions of systems and software engineering terms
- Definitions may be reprinted (with attribution).
- Currency of database will be maintained by a vocabulary standards project coordinated between IEEE and ISO/IEC JTC 1/SC 7, and published as ISO/IEC/IEEE 24765.
- Sources:
  - IEEE standards
  - ISO/IEC standards
  - Other sources
# The State of Harmonization

<table>
<thead>
<tr>
<th>Topic</th>
<th>Status</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terminology &amp; Concepts</strong></td>
<td>Yellow</td>
<td>Shared BOK, joint vocabulary project, potential certification framework</td>
</tr>
<tr>
<td><strong>Quality management</strong></td>
<td>Yellow</td>
<td>IEEE is adopting ISO/IEC 90003 approach.</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td>Orange</td>
<td>Both IEEE and BSI will harmonize with SC7 processes.</td>
</tr>
<tr>
<td><strong>Architecture description</strong></td>
<td>Green</td>
<td>SC7 adopted IEEE standard and will harmonize with processes.</td>
</tr>
<tr>
<td><strong>Product quality</strong></td>
<td>Yellow</td>
<td>ISO/IEC 12119 was revised as 25051. IEEE will withdraw its standard.</td>
</tr>
<tr>
<td><strong>Life cycle processes</strong></td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td><strong>Systems engineering</strong></td>
<td>Green</td>
<td>Shared SE process standard; harmonization with other LC processes underway</td>
</tr>
<tr>
<td><strong>SW maintenance</strong></td>
<td>Green</td>
<td>Project to merge IEEE and ISO standards is completed</td>
</tr>
<tr>
<td><strong>Measurement</strong></td>
<td>Green</td>
<td>Some details remain.</td>
</tr>
<tr>
<td><strong>Risk management</strong></td>
<td>Green</td>
<td>SC7 adopted IEEE standard and is now extending it to the systems level.</td>
</tr>
<tr>
<td><strong>Project management</strong></td>
<td>Yellow</td>
<td>Project is merging the incompatible standards.</td>
</tr>
<tr>
<td><strong>Verification and validation</strong></td>
<td>Red</td>
<td>Fundamentally different approaches. Good intentions, but no action yet.</td>
</tr>
<tr>
<td><strong>Configuration management</strong></td>
<td>Yellow</td>
<td>SC7 withdrew its standard; systems issues remain. IEEE is about to revise.</td>
</tr>
<tr>
<td><strong>SW process assessment</strong></td>
<td>Yellow</td>
<td>Harmonization with LC process standards is underway</td>
</tr>
<tr>
<td><strong>Requirements engineering</strong></td>
<td>Orange</td>
<td>Joint project has been approved; mashup of relevant standards is being prepared.</td>
</tr>
<tr>
<td><strong>SW life cycle data</strong></td>
<td>Yellow</td>
<td>IEEE is adopting 15289 to replace 12207.1</td>
</tr>
<tr>
<td><strong>User documentation</strong></td>
<td>Yellow</td>
<td>IEEE 1063 has been incorporated into 26514. IEEE will adopt it.</td>
</tr>
<tr>
<td><strong>CASE tools</strong></td>
<td>Yellow</td>
<td>Minor incompatibilities</td>
</tr>
<tr>
<td><strong>Notations</strong></td>
<td>Harmless</td>
<td>Distinct standards for distinct notations</td>
</tr>
<tr>
<td><strong>Internet</strong></td>
<td>Green</td>
<td>Shared standard</td>
</tr>
<tr>
<td><strong>IT Services, Management, Governance</strong></td>
<td>Yellow</td>
<td>IEEE will adopt 20000 standards</td>
</tr>
<tr>
<td><strong>Specialty Engineering (Safety, Security)</strong></td>
<td>Orange</td>
<td>Unrelated approaches will be addressed in part by coordination revision of 15026</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>SSTC 2009</td>
<td>Many unrelated standards</td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td></td>
</tr>
</tbody>
</table>
Code of Ethics
Software Engineering Code of Ethics and Professional Practices


“The short version of the code summarizes aspirations at a high level of the abstraction; the clauses that are included in the full version give examples and details of how these aspirations change the way we act as software engineering professionals. Without the aspirations, the details can become legalistic and tedious; without the details, the aspirations can become high sounding but empty; together, the aspirations and the details form a cohesive code.”
Short Version States Eight Principles

- **Public:** Software engineers shall act consistently with the public interest.
- **Client and employer:** Software engineers shall act in a manner that is in the best interests of their client and employer consistent with the public interest.
- **Product:** Software engineers shall ensure that their products and related modifications meet the highest professional standards possible.
- **Judgment:** Software engineers shall maintain integrity and independence in their professional judgment.
- **Management:** Software engineering managers and leaders shall subscribe to and promote an ethical approach to the management of software development and maintenance.
- **Profession:** Software engineers shall advance the integrity and reputation of the profession consistent with the public interest.
- **Colleagues:** Software engineers shall be fair and supportive of their colleagues.
- **Self:** Software engineers shall participate in lifelong learning regarding the practice of their profession and shall promote an ethical approach to the practice of the profession.
Example from Long Version

Principle 4 JUDGMENT Software engineers shall maintain integrity and independence in their professional judgment. In particular, software engineers shall, as appropriate:

4.01. Temper all technical judgments by the need to support and maintain human values.

4.02. Only endorse documents either prepared under their supervision or within their areas of competence and with which they are in agreement.

4.03. Maintain professional objectivity with respect to any software or related documents they are asked to evaluate.

4.04. Not engage in deceptive financial practices such as bribery, double billing, or other improper financial practices.

4.05. Disclose to all concerned parties those conflicts of interest that cannot reasonably be avoided or escaped.

4.06. Refuse to participate, as members or advisors, in a private, governmental or professional body concerned with software related issues, in which they, their employers or their clients have undisclosed potential conflicts of interest.
Backup
Consensus Process

• Four lead editors
• 21 KA editors (for 10 KAs)
• 10 organizations on Industrial Advisory Board
• Four rounds of review and comment disposition, using a variety of populations
• A total of about 10,000 comments
• Nearly 600 individual reviewers
  – About half were non-US
  – Roughly equal split: BS, MS, PhD
  – Roughly equal split: 0-50 employees, 50-500, 500+
SE 2004 Process

- Objective: Provide guidance to academic institutions and accreditation agencies about what should constitute an undergraduate software engineering education

- Consensus Process:
  - 65 volunteers: 29 US and 36 non-US
  - International representation on the Steering Committee
  - Internal review by international SE experts
  - Review by industrial advisory panel
  - Multiple review cycles with steering committee responses to all issues
Examples of SWEBOK Uptake

- Available for free on the web (http://www.swebok.org) and in book form
- Translated (or translating) into Japanese, Chinese, Spanish, French, Russian, Hungarian, Arabic
- CSDA, CSDP, SE2004, GSwERC, CCPE and IFIP IP3 cite SWEBOK Guide as a source
- SWEBOK Guide was adopted as ISO/IEC TR 19759
- A large defense contractor has experimented with the Guide to calibrate skills descriptions in proposals.
- An FFRDC has rewritten its “Software Systems Engineer” job description in terms of the SWEBOK knowledge areas.
- Construx, Inc. has rewritten its position descriptions in terms of the Guide, structures its professional development around the Guide.
- NTU and SMU have rationalized their software engineering offerings using the SWEBOK.
- SWEBOK provides the taxonomical basis for VISEK, a SWE Portal funded by the German government.
- 155,000 Google hits on “SWEBOK” in May 2007
Professional Societies in Accreditation

• Professional Societies work with accrediting agencies to assure that the technical criteria are appropriate.

• For example ABET works with the ACM, IEEE, and other engineering and technical societies to assure that engineering and technical accreditation are based on sound criteria, and on what industry needs.
Accreditation Board for Engineering and Technology

- Engineering Accreditation Commission: 1819 accredited programs at 370 institutions
- Technology Accreditation Commission: 698 accredited programs at 233 institutions
- Applied Science Accreditation Commission: 70 accredited programs at 53 institutions
- Computing Accreditation Commission: 300 accredited programs at 236 institutions

Numbers do not include 2008 cycle
A standard is a name for an otherwise fuzzy concept

In a complex, multidimensional trade space of solutions ...

... a standard gives a name to a bounded region.

It defines some characteristics that a buyer can count on.