New Guidelines for Graduate Software-Engineering Education

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A new set of guidelines for graduate software-engineering education was recently published by Stevens Institute of Technology. These recommendations were developed by a coalition formed in 2007 from academia, industry, government, and professional societies called the Integrated Software and Systems Engineering Curriculum (iSSEc) project, to create a reference curriculum that reflects current development practices and the greater role of software in today’s systems. The report, titled Graduate Software Engineering 2009 (GSwE2009): Curriculum Guidelines for Graduate Degree Programs in Software Engineering, is available at http://www.gswe2009.org. Earlier versions of this work used the name “Graduate Software Engineering Reference Curriculum (GSwERC).”

One of the primary goals of the iSSEc project was the incorporation and integration of systems-engineering knowledge and practices into graduate software-engineering programs. Large systems today include significant software content. The software engineers who work on these systems need to understand better the relationships between hardware, software and human components. INCOSE has been an active member of the iSSEc project, participating in authorship, review, and promotion of the effort.

We are indebted to the many experts who helped create the guidelines. A complete list of those participants and their supporting organizations is included in the report. We are especially grateful to Kristen Baldwin and others in the U.S. Office of the Secretary of Defense for their consistent, generous and thoughtful support of this project.

History of the Project

In 1989 the Software Engineering Institute (SEI) of Carnegie Mellon University published a landmark report on graduate education in software engineering (Ardis and Ford 1989). Several universities in establishing their software-engineering degree programs used the recommendations in that report. Since then the way software is developed has changed dramatically. Software’s scale, complexity, and criticality have mushroomed, yet no significant effort has been made to revisit and update the original SEI recommendations.

GSwE2009 builds on the SEI curriculum foundations plus those of other initiatives, such as the Guide to the Software Engineering Body of Knowledge (SWEBOK; Bourque and Dupuis 2004) and Software Engineering 2004: Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering (ACM and IEEE 2004). The iSSEc project followed an iterative, evolutionary approach in creating GSwE2009, beginning with the formation of a curriculum author team (CAT). First established in July 2007, the CAT is a set of invited experts from industry, government, academia, and professional associations. CAT membership grew as GSwE2009 matured.
The CAT met in workshops approximately every three months between August 2007 and September 2009, leading to the release of GSwERC 0.25 in February 2008, GSwERC 0.5 in October 2008, and GSwE2009 1.0 in September 2009. The software-engineering community was invited to review versions 0.25 and 0.5 to provide the necessary feedback to develop the current version (1.0). The review of version 0.5 generated more than 800 individual review comments, which were adjudicated for use in creating version 1.0. The detailed comments and their adjudication can be found at http://www.GSwE2009.org.

Professional-society participation in the creation of GSwE2009 has been essential to ensuring that GSwE2009 will have the desired impact on global graduate education. Both INCOSE and the U.S. National Defense Industrial Association (NDIA) Systems Engineering Division were early participants in GSwE2009, and each contributed authors. In 2008, the Institute of Electrical and Electronics Engineers (IEEE) Computer Society Education Activities Board became an official participant. In 2009 the Association for Computing Machinery (ACM), the IEEE Computer Society, and the Brazilian Computer Society (BCS) also chose to participate. Discussions are underway with the ACM, IEEE Computer Society, and INCOSE in the hope that they will jointly take on the evolution and maintenance of GSwE2009. Finally, GSwE2009’s success has motivated the start of related efforts to create a Systems Engineering Body of Knowledge and a Graduate Systems Engineering Reference Curriculum—each with an “appropriate” amount of software engineering perspective and content. Those efforts should lead to version 1.0 products in 2012.

Content of Curriculum Recommendations

GSwE2009 includes the following elements:

- A set of outcomes to be fulfilled by a student who successfully completes a graduate program based on the curriculum
- A set of student skills, knowledge, and experience assumed by the curriculum, not intended as entrance requirements for a specific program, but as the starting point for the curriculum’s outcomes
- An architectural framework to support implementation of the curriculum
- A description of the fundamental or core skills, knowledge, and practice to be taught in the curriculum to achieve the outcomes. This is termed a *Core Body of Knowledge* (CBOK) and includes topic areas and the depth of understanding a student should achieve.

A university considering the creation or modification of a graduate software engineering program should be able to use the CBOK and the architectural framework to design appropriate courses and degree requirements. The outcomes and entrance assumptions should help in determining the expected market and value of the program to potential students and their employers.

In addition, GSwE2009 includes the following:
• The fundamental philosophy for GSwE2009 development as described in a set of guiding principles
• A discussion of how GSwE2009 will evolve to remain effective
• A mapping of expected outcomes to the CBOK and to the total GSwE2009 program recommendations
• A description of Knowledge Areas (KAs) discussed in GSwE2009 that are not yet fully integrated into the current version of the Software Engineering Body of Knowledge (SWEBOK)
• Glossary, references, and other supporting material.

**Expected Student Outcomes**

Graduates of a master’s program that satisfies GSwE2009 recommendations will do the following:

• Master the Core Body of Knowledge (CBOK).
• Master software engineering in at least one application domain, such as finance, medical, transportation, or telecommunications, and one application type, such as real-time, embedded, safety-critical, or highly distributed systems. That mastery includes understanding how differences in domain and type manifest themselves in both the software itself and in its engineering, and includes understanding how to learn a new application domain or type.
• Master at least one Knowledge Area (KA) or subarea from the CBOK to at least the Bloom Synthesis level (Bloom 1956).
• Be able to make ethical professional decisions and practice ethical professional behavior.
• Understand the relationship between software engineering and systems engineering and be able to apply systems-engineering principles and practices in the engineering of software.
• Be an effective member of a team, including teams that are international and geographically distributed, effectively communicate both orally and in writing, and lead in one area of project development, such as project management, requirements analysis, architecture, construction, or quality assurance.
• Be able to reconcile conflicting project objectives, finding acceptable compromises within limitations of cost, time, knowledge, existing systems, and organizations.
• Understand and appreciate feasibility analysis, negotiation, and good communications with stakeholders in a typical software development environment, and be able to perform those tasks well; have effective work habits and be a leader.
• Be able to learn new models, techniques, and technologies as they emerge, and appreciate the necessity of such continuing professional development.
• Be able to analyze a current significant software technology, articulate its strengths and weaknesses, compare it to alternative technologies, and specify and promote improvements or extensions to that technology.
Curriculum Architecture

Figure 1 provides an overview of the curriculum architecture. GSwE2009 identifies the fundamental skills and knowledge that all graduates of a master’s program in software engineering must possess. This is captured in the half-circle area labeled Core Materials. These skills and knowledge include such topics as systems engineering fundamentals, requirements engineering, software design, and ethics and professional conduct.

The next half-circle in figure 1, labeled University-Specific Materials, represents materials that an institution might include in order to tailor its program to meet its specific objectives. These will vary by institution or degree program. For example, a program that emphasizes safety-critical systems might have a required course on such systems that would be part of the university-specific materials.

Elective Materials accommodate different interests of individual students, but may still reflect a program focus. For example, a program may focus on information security, verification and validation (V&V), or health-care systems, providing a series of courses that allow a student to gain depth in a technical area.

Figure 1. GSwE2009 curriculum architecture
Core Body of Knowledge

The Core Body of Knowledge (CBOK) includes all of the fundamental or core skills, knowledge, and experience to be taught in the curriculum to achieve the expected student outcomes. The primary source for developing the CBOK was the SWEBOK. Knowledge elements were also derived from the Software Engineering 2004 curriculum guidelines (ACM and IEEE 2004), the INCOSE Guide to Systems Engineering Body of Knowledge (INCOSE 2004) and especially the INCOSE Systems Engineering Handbook (Haskins 2007).

Figure 2 shows the knowledge elements of CBOK and their expected relative proportions of the GSwE2009 curriculum. Although specific systems engineering knowledge elements only represent 2–3% of the CBOK, they are considered a crosscutting concern that arises in many other areas. For example, systems engineering material would also be covered under requirements engineering, testing, configuration management and project management.

Figure 2. CBOK knowledge elements as percentages of GSwE2009 curriculum

Systems Engineering in the Curriculum

Of particular interest to INSIGHT readers should be the discussion of the systems-engineering knowledge area and its integration into the curriculum guidelines. You are encouraged to review, for example, section 6.5 on “Systems Engineering Issues” of the CBOK and appendix C.2, “Systems Engineering.”

The iSSEc project has just completed two companion reports to help schools interested in creating or modifying graduate software engineering programs. The first report compares current programs to the guidelines, and the second answers common questions about implementation of
graduate degree programs in software engineering. Please visit the GSwE2009 Web site, http://www.gswe2009.org, to download the reports. You may also use the site to submit comments or questions. Your help in improving the recommendations is greatly appreciated.

References


