Continuing education curricula and competency matching in the area of Digital Transformation (DX): Cases of Smart SE, SFIA, and CC2020

Hironori Washizaki
Director of Smart SE
Professor at Waseda University, Tokyo, Japan
washizaki@waseda.jp

https://www.waseda.jp/culture/news/2020/04/30/10381/
Prof. Dr. Hironori Washizaki

- Waseda University in Tokyo
  - Professor and the Associate Dean of the Research Promotion Division
  - **Leading Smart SE: Lifelong education of IoT/AI/DX**
  - Leading projects on STEM education

- Academia and industry
  - National Institute of Informatics, Visiting Professor
  - SYSTEM INFORMATION and eXmotion, Outside Directors

- Professional communities
  - IEEE Computer Society, 1st Vice President
  - IEEE Transactions on Emerging Topics in Computing, Associate Editor
  - MDPI Education Sciences, Editorial Board Member
  - ISO/IEC/JTC1 SC7/WG20, Convener
  - IEEE Conference on Software Engineering Education and Training (CSEE&T), Steering Committee Member
  - IEEE COMPSAC, Advisory Committee Member
  - Asia-Pacific Software Engineering Conference (APSEC), Steering Committee Member
1. Smart SE in the era of DX and 60-year curriculum

2. Practical features in Smart SE

3. Curriculum evaluation based on SFIA Framework

4. Comparison between Industry and University: SFIA Framework and CC2020
Digital transformation (DX)

• Overall activity of using digital technologies to renew the value proposition to customers and to transform the related business and operations [Barman12] [Jonathan20].

• Transformation of business models to create customer-driven values through data and digital technologies [Washizaki20]

• Professionals who lead DX by using digital technologies are expected.


60-year curriculum: New perspective on continuing education

- Concept proposed by Gary Matlin (University of California, Irvine), John Richards and Chris Dede (Harvard Graduate School of Education)
- Centered on six decades of employment
- Requiring a lifetime of learning in the context of repeated occupational change and transition
- Features of 60-years curriculum in global network
  - Consulting and entrepreneurship
  - Digitalization
  - Transferable skills
  - Agile network

https://er.educause.edu/articles/2020/10/the-60-year-curriculum-a-strategic-response-to-a-crisis
Smart SE : Smart Systems and Services
innovative professional Education program

https://www.waseda.jp/inst/smartse/en

■ Head: Waseda University
■ Partner universities including:
Ibaraki University; Gunma University; Tokyo Gakugei University; Tokyo Institute of Informatics;
Osaka University; Kyushu University; Japan Advanced Institute of Science and Technology;
Nara Advanced Institute of Science and Technology; Tokyo University of Technology; Toyo University; Tsurumi University; National Institute of Informatics
■ 21 Partner companies and organizations (at the time of enPiT-Pro program)
Toshiba; Fujitsu; NEC; Hitachi; e-Seikatsu; Yahoo; Whole Brain Architecture Initiative; Denso;
Halex; Medical Information Company for Innovation; System Information; Mobile Computing Promotion Consortium; Japan Association of New Economy; Information Technology Federation of Japan; IT Verification Industry Association; Japan Society of Next Generation Sensor Technology; Japan Electronics and Information Technology Industries Association; Japan Embedded Systems Technology Association; Computer Software Association of Japan;
Advanced IT Consortium to Evaluate, Apply and Drive; Weather Business Consortium
Smart SE: Recurrent Education Program of IoT and AI for Business in the era of DX

- **Consulting and entrepreneurship**: Business and value
- **Digitalization**: AI, IoT and other advanced digital technologies
- **Transferable skills**: Agile mind, capstone projects (continuous collaboration)
- **Agile network**: Networking, nation-wide industry-academia collaboration
Curriculum over different layers in digital transformation (DX) era

- Necessary viewpoint
- Data-driven and comprehensive approach
- Connection with Businesses and values
- Various objectives and contexts

Solution

- Full-stack curriculum and common problems
- Business and design thinking, PBL, capstone
- Ease of course combinations, on-demand

Business

IoT innovation
IoT and systems approach
IoT business model hypothesis verification

Practical integration

Application

- Embedded and realtime system
- Architecture and quality engineering

Information processing

- Machine learning
- Big data
- Knowledge processing and NLP

IoT communication
And wireless sensor network

Cloud computing foundation

Sensor

Smart IoT system business Intro.

SmartSE

Global PBL

Capstone project (solving actual problems)

Network and CPS

Information processing

Architecture and quality engineering

Embbeded and realtime system

IoT innovation

IoT and systems approach

IoT business model hypothesis verification

Security, privacy and law

Cloud and business innovator

Practical integration

IoT communication
And wireless sensor network

Cloud computing foundation

Sensor

Smart IoT system business Intro.
Industry-academia collaboration network (at the time of enPiT-Pro)
Agenda

1. Smart SE in the era of DX and 60-year curriculum

2. Practical features in Smart SE

3. Curriculum evaluation based on SFIA Framework

4. Comparison between Industry and University: SFIA Framework and CC2020
Practical features in Smart SE

1. Comprehensive program sets and blended learning
   • MOOC and on-demand lectures
   • Project-based learning (PBL)
2. Quality assurance in education
   • Course evaluation and interview
3. Feedback loop of education and research
   • Individual subject (e.g., integrated modeling method)
   • Automated review of entire program
1. Blended learning

Remote lecture and class-room solo and team exercise (practice)

**Group work without devices**
- Breakout rooms in Zoom
- Online collaboration using Google documents

**Individual work with devices**
- Change to individual exercise by shipping devices
- On-demand videos and live-stream of lecturer’s instructions

---

Smart Systems and Services innovative professional Education program
<table>
<thead>
<tr>
<th>MOOC and on-demand lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>JMOOC/gacco</strong></td>
</tr>
<tr>
<td>- 13 lecture courses</td>
</tr>
<tr>
<td>- 20,000-30,000 learners/year</td>
</tr>
<tr>
<td>- In Japanese</td>
</tr>
<tr>
<td><strong>edX</strong></td>
</tr>
<tr>
<td>- 1 lecturer</td>
</tr>
<tr>
<td>- 2,000-3,000 learners/year</td>
</tr>
<tr>
<td>- In English</td>
</tr>
</tbody>
</table>

*WASEDA University*
Project-based learning (PBL)

Online group work
• Business model canvas
• Architecture design
• Cloud, AWS, Raspberry Pi
• Deep learning

Exercise in assembly format
• Team work mixing engineers and university students
• AWS Deep racer
• Reinforcement learning
2. Quality assurance in education

- Learners’ course evaluations to improve each course content
- Course text review by subject matter experts
  - E.g., a course division into multiple courses
- Learner interview one year after graduation to confirm and improve entire program
  - 2019: 60-80% respondents (N=10) answered the program was useful for developing and improving their businesses.
  - 2020: 85% respondents (N=13) answered the program was useful for developing and improving their businesses.
3. Feedback loop of education and research

Education
- Identifying potential problems
- E.g., IoT systems involving IoT business and systems modeling

Research
- Solving problems
- E.g., Integration of GQM+Strategies and SysML

- Horizontal Relation Identification Method to Handle Misalignment of Goals and Strategies Across Organizational Units, IEEE Access 7(1), 2019
- Systematical Alignment of Business Requirements and System Functions by Linking GQM+Strategies and SysML, Int. J. Service and Knowledge Management 5(1), 2021
- Continuous modeling supports from business analysis to systems engineering in IoT development, Int. J. Service and Knowledge Management 6, 2022
1. Smart SE in the era of DX and 60-year curriculum

2. Practical features in Smart SE

3. Curriculum evaluation based on SFIA Framework

4. Comparison between Industry and University: SFIA Framework and CC2020
Mapping course contents to knowledge/skill/competency frameworks

- Identifying strength and weakness (and potential extension) of the program
- Reference frameworks
  - Bodies of Knowledge: SWEBOK, INCOSE SE Handbook, PMBOK, …
  - Skill framework: **SFIA framework**, e-CF, …
  - Competency framework: i Competency Dictionary (iCD), SWECOM, …
SFIA: Skills Framework for the Information Age

- Global de facto standard IT Skill Framework for industry
  - Used more than 200 countries
  - Translated in 11 languages
  - [https://sfia-online.org/en](https://sfia-online.org/en)

- Free of charge for most non-commercial uses. Charged for business users

- National IT Skill Standard in Australia, Saudi Arabia etc.

- the globally accepted common language for the skills and competencies for the digital transformation world.

History
- 2021 – SFIA V8
- 2018 – SFIA V7
- 2015 – SFIA V6
- 2011 – SFIA V5
- 2008 – SFIA V4
- 2005 – SFIA V3
- 2003 – SFIA Foundation Formed
- 2001 – SFIA V2
- 2000 – SFIA V1
- 1990 – 1998 Various UK initiatives

SFIA : Contents

6 Categories

- Strategy and architecture (27)
- Change and transformation (12)
- Development and implementation (20)
- Delivery and operation (20)
- Skills and quality (14)
- Relationships and engagement (9)

7 Level of Responsibilities (LoR)

102 Skills

SFIA Skill = Competency

Exemplar mapping: Smart SE on SFIA DX view

- Smart SE IoT/AI courses cover 11 out of 49 skills in SFIA DX view
  - Digital tech. 33%, digital strategy 29%, digital/data 21%

<table>
<thead>
<tr>
<th>Category</th>
<th>Skill</th>
<th>IoT business model</th>
<th>IoT innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital strategy, innovation and investments</td>
<td>Strategic planning</td>
<td></td>
<td>Service innovation design</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emerging technology monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>User research</td>
<td>Interview and hypothesis verification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>User experience design</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business process improvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business situation analysis</td>
<td>Business model canvas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portfolio management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feasibility assessment</td>
<td>Lean startup</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investment appraisal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enterprise and business architecture</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Product management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Smart SE in the era of DX and 60-year curriculum

2. Practical features in Smart SE

3. Curriculum evaluation based on SFIA Framework

Comparison of required skills and competencies between Industry and University

University

CC2020

Comparison

Competency vs Competency

Competency = “I can do this”

Industry

SFIA V7

The IT Curriculum Global Standard (ACM and IEEE-CS)

The IT Skill Framework Global de facto Standard (SFIA Foundation)

CC2020: Computing Curricula

CC2005

- a task force of 50 people from 20 countries
- Knowledge-based competency-based

CC2020 Computing Disciplines

| CE | CS | IS | IT | SE | CSEC | DS |

Competency = Knowledge + Skills + Dispositions

- Knowledge—"know-what"
- Skills—"know-how"
- Dispositions—"know-why"

- Computer Engineering Curricula 2016 (CE2016)
- Computer Science Curricula 2013 (CS2013)
- Information Systems 2010 (IS2010)
- Information Technology Curricula 2017 (IT2017)
- Software Engineering Curricula 2014 (SE2014)
- Cybersecurity Curricula 2017 (CSEC2017)
- Data Science Curricula 2021 (DS2021)

Comparison: CC2020 vs SFIA V7

**Industry**
- Depends on universities for the basic curriculum
- Access curriculum with universities

**University**
- Keep the basic curriculums
- Needs consideration under the discussion with the industry whether these competencies are useless or not.

**CC2020 Competencies**

**SFIA V7 Skills**
- Exist in SFIA, but not in CC2020 (B)
- Exist in SFIA and CC2020 (A)
- Exist in SFIA, but not in CC2020 (C)

**Industry**
- Need training for new graduates
- OJT, Education Programs

**University**
- Add to university curriculum or leave it to the industry
- Collaborate with industries

**RQ1:** How much CC2020 and SFIA are matching each other?
**RQ2:** For unmatched areas, what is the reason, and how should the university and IT industry should understand?
RQ1: How much CC2020 and SFIA are matching each other?

RQ1: How much CC2020 and SFIA are matching each other? (A) (cont.)

CC2020 covers 65% (66 out of 102) skills of SFIA V7

<table>
<thead>
<tr>
<th>SFIA categories</th>
<th># of SFIA skills matching/unmatching to CC2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFIA all</td>
<td>66</td>
</tr>
<tr>
<td>Strategy and architecture</td>
<td>18</td>
</tr>
<tr>
<td>Change and transformation</td>
<td>9</td>
</tr>
<tr>
<td>Development and implement</td>
<td>18</td>
</tr>
<tr>
<td>Delivery and operation</td>
<td>15</td>
</tr>
<tr>
<td>Skills and quality</td>
<td>6</td>
</tr>
<tr>
<td>Relationships and engage</td>
<td>4</td>
</tr>
<tr>
<td>Unmatch</td>
<td>36</td>
</tr>
<tr>
<td>Match</td>
<td>66</td>
</tr>
</tbody>
</table>

RQ2: For the unmatched area, what is the reason and?

**Unmatched skills**
- **Business-related Skills** 10(28%)
- **Organization-related Skills** 18(50%)
- **Advanced technology-related Skills** 8(22%)

<table>
<thead>
<tr>
<th>Skill Category</th>
<th>Strategy and architecture</th>
<th>Change and transformation</th>
<th>Development and implement</th>
<th>Delivery and operation</th>
<th>Skills and quality</th>
<th>Relationships and engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill Name</td>
<td>ISCO INAN VISL ICPM CNSL TECH RSCH SUST POMG BUAN BSMO OCDV OCVI ORDY CIPM BENM ADEV PORT CHMG CHGM RDEN PBMG USUP TMCR TDL TEAC MEAS CORE CSMG MKTG SALE SSUP PROD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmatched Reason</td>
<td>2 3 3 2 1 2 2 3 2 2 1 1 2 2 1 1 3 3 3 3 3 2 2 2 2 2 1 2 2 1 1 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## RQ2: For the unmatched area, what is the reason? (C)

<table>
<thead>
<tr>
<th>Category</th>
<th>SFIA V7 covers 68% (49 out of 72) competencies of CC2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td></td>
</tr>
<tr>
<td>CE-CAE Circuits and Electronics</td>
<td></td>
</tr>
<tr>
<td>CE-CAL Computing Algorithm</td>
<td></td>
</tr>
<tr>
<td>CE-CAO Computer Architecture &amp; Organization</td>
<td></td>
</tr>
<tr>
<td>CE-DIG Digital Design</td>
<td></td>
</tr>
<tr>
<td>CE-ESY Embedded System</td>
<td></td>
</tr>
<tr>
<td>CE-NWK Computer Networks</td>
<td>✓</td>
</tr>
<tr>
<td>CE-SEC Information Security</td>
<td></td>
</tr>
<tr>
<td>CE-SGP Signal Processing</td>
<td></td>
</tr>
<tr>
<td>CE-SPE Systems and Project Engineering</td>
<td></td>
</tr>
<tr>
<td>CE-SRM System Resource Management</td>
<td>✓</td>
</tr>
<tr>
<td>CE-SWD Software Design</td>
<td>✓</td>
</tr>
<tr>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>AL-Algorithms and Complexity</td>
<td></td>
</tr>
<tr>
<td>AR-Architecture and Organization</td>
<td></td>
</tr>
<tr>
<td>CN-Computational Science</td>
<td></td>
</tr>
<tr>
<td>DS-Discrete Structure</td>
<td></td>
</tr>
<tr>
<td>GV-Graphics and Visualization</td>
<td></td>
</tr>
<tr>
<td>HCI-Human-Computer Interaction</td>
<td>✓</td>
</tr>
<tr>
<td>IAS-Information Assurance and Security</td>
<td>✓</td>
</tr>
<tr>
<td>IM-Information Management</td>
<td>✓</td>
</tr>
<tr>
<td>IS-Intelligent Systems</td>
<td></td>
</tr>
<tr>
<td>NC-Networking and Communication</td>
<td>✓</td>
</tr>
<tr>
<td>OS-Operating Systems</td>
<td></td>
</tr>
<tr>
<td>PBD-Platform-based Development</td>
<td>✓</td>
</tr>
<tr>
<td>PD-Parallel and Distributed Computing</td>
<td></td>
</tr>
<tr>
<td>PL-Programming Languages</td>
<td>✓</td>
</tr>
<tr>
<td>SDF-Software Development Fundamentals</td>
<td>✓</td>
</tr>
<tr>
<td>SE-Software Engineering</td>
<td>✓</td>
</tr>
<tr>
<td>SF-Systems Fundamentals</td>
<td>✓</td>
</tr>
<tr>
<td>SP-Social Issues and Professional Practice</td>
<td>✓</td>
</tr>
<tr>
<td>IS</td>
<td></td>
</tr>
<tr>
<td>Identifying and designing opportunities for IT-enabled organizational improvement</td>
<td>✓</td>
</tr>
<tr>
<td>Analyzing trade-offs</td>
<td>✓</td>
</tr>
<tr>
<td>Designing and improving information systems solution</td>
<td>✓</td>
</tr>
<tr>
<td>Managing ongoing information technology operations</td>
<td>✓</td>
</tr>
<tr>
<td>Leadership and collaboration</td>
<td>✓</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>Negotiation</td>
<td></td>
</tr>
<tr>
<td>Analytical and critical thinking, including creativity and ethical analysis</td>
<td></td>
</tr>
<tr>
<td>Mathematical foundations</td>
<td></td>
</tr>
</tbody>
</table>

Unmatched reasons:

- Fundamental Science Competencies 10 (28%)
- SFIA LoR definition, not SFIA skills 4 (17%)
- Competency unknown 1 (4%)
- Not Industrial Issues 2 (9%)
RQ2: For the unmatched area, what is the reason? (C) (cont.)

<table>
<thead>
<tr>
<th>Category</th>
<th>SFIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT-CSP Cybersecurity Principles</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-GPP Global Professional Practices</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-IMA Information Management</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-IST Integrated Systems Technology</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-NET Networking</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-PFT Platform Technologies</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-SPA System Paradigms</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-SWF Software Fundamentals</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-UXD User Experience Design</td>
<td>✓</td>
</tr>
<tr>
<td>ITE-WMF Web and Mobile Systems</td>
<td>✓</td>
</tr>
<tr>
<td>Software Requirement</td>
<td>✓</td>
</tr>
<tr>
<td>Software Design</td>
<td>✓</td>
</tr>
<tr>
<td>Software Construction</td>
<td>✓</td>
</tr>
<tr>
<td>Software Testing</td>
<td>✓</td>
</tr>
<tr>
<td>Software Sustainment</td>
<td>✓</td>
</tr>
<tr>
<td>Software Process and Life Cycle</td>
<td>✓</td>
</tr>
<tr>
<td>Software Systems Engineering</td>
<td>✓</td>
</tr>
<tr>
<td>Software Quality</td>
<td>✓</td>
</tr>
<tr>
<td>Software Security</td>
<td>✓</td>
</tr>
<tr>
<td>Software Safety</td>
<td>✓</td>
</tr>
<tr>
<td>Software Configuration Management</td>
<td>✓</td>
</tr>
<tr>
<td>Software Measurement</td>
<td>✓</td>
</tr>
<tr>
<td>Human-Computer Interaction</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>✓</td>
</tr>
<tr>
<td>Behavioral Attributes</td>
<td>✓</td>
</tr>
<tr>
<td>Data</td>
<td>✓</td>
</tr>
<tr>
<td>Software</td>
<td>✓</td>
</tr>
<tr>
<td>Component</td>
<td>✓</td>
</tr>
<tr>
<td>Connection</td>
<td>✓</td>
</tr>
<tr>
<td>System</td>
<td>✓</td>
</tr>
<tr>
<td>Human</td>
<td></td>
</tr>
<tr>
<td>Organizational</td>
<td>✓</td>
</tr>
<tr>
<td>Societal</td>
<td></td>
</tr>
</tbody>
</table>

SFIA V7 covers 68% (49 out of 72) competencies of CC2020

Unmatched reasons:
- Fundamental Science Competencies 10 (28%)
- SFIA LoR definition, not SFIA skills 4 (17%)
- Competency unknown 1 (4%)
- Not Industrial Issues 2 (9%)
Summary

- Smart SE: Recurrent education of IoT and AI for Business
  - DX and 60-year curriculum
  - Comprehensive program sets: MOOC and PBL
  - Quality assurance

- Mapping course contents to skill and competency frameworks to identify strengths and weaknesses
  - SFIA: Skills Framework for the Information Age
  - Smart SE IoT/AI courses cover 22% (11 out of 49) skills in SFIA V8 DX view

- Comparison of required skills and competencies between Industry and Academia
  - CC2020 covers 65% (66 out of 102) skills of SFIA V7
  - SFIA V7 covers 68% (49 out of 72) competencies of CC2020

https://www.waseda.jp/inst/smartse/en

“Smart SE: Smart Systems and Services Innovative Professional Education Program,” COMPSAC 2020
“Automated educational program mapping on learning standards in computer science,” COMPSAC 2021
“The Competency-based Computing Curricula 2020 and SFIA V7 comparison focusing on Digital Transformation Age,” EDUNINE 2022