Smart SE: Recurrent Education Program of IoT and AI for Business in the Era of Digital Transformation and 60-Year Curriculum

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• Professor and the Associate Dean of the Research Promotion Division at Waseda University in Tokyo
• Visiting Professor at the National Institute of Informatics
• Outside Directors of SYSTEM INFORMATION and eXmotion
• **Leading Smart SE**
• Leading projects on STEM education with a particular focus on introductory programming environments
• IEEE Computer Society Vice President for Professional and Educational Activities
• Associate Editor of IEEE Transactions on Emerging Topics in Computing
• Editorial Board Member of MDPI Education Sciences
• Steering Committee Member of the IEEE Conference on Software Engineering Education and Training (CSEE&T)
• Advisory Committee Member of the IEEE CS flagship conference COMPSAC
• Convener of ISO/IEC/JTC1 SC7/WG20
• [http://www.washi.cs.waseda.ac.jp/](http://www.washi.cs.waseda.ac.jp/)
Smart SE: Smart Systems and Services
innovative professional Education program

https://smartse.jp/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
Agenda

• Smart SE in the era of DX and 60-year curriculum
• Practical features in Smart SE
  • Comprehensive program sets
  • Quality assurance
  • Feedback loop of education and research
• Related activities in IEEE-CS PEAB
enPiT-Pro: Systematic, advanced, and short-term ICT practical recurrent education program with industry-academia network in Japan

**Background**

- Industry 4.0, uncertainty
- Work style reform, shortage of ICT professionals
- MEXT undergraduates and graduates education

**Features**

- ’22- Recurrent education program by consortium
- Industry-academia collaboration
- Practical, MOOC, project-based learning

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**SmartSE**  
IoT, AI and Business  
Waseda University, Ibaraki, Gunma, Tokyo Gakugei, Tokyo Tech., Osaka, Kyushu, JAIST, NAIST, Kogakuin, Tokyo Univ. Tech., Toyo, Tsurumi, NII

**Open IoT**  
IoT, ICT  
Toyo University, U. Tokyo, Yokohama National, Nagoya, Meijo

**ProSec**  
Information Security  
Institute of Info. Security, Tohoku, Osaka, Wakayama, Kyushu, Nagasaki Pref., Keio

**enPiT-Pro Emb**  
Automotive, Embedding, IoT  
Nagoya University, Shizuoka, Hiroshima, Ehime, Nanzan

**SI-IoTAiR**  
AI, IoT, Robotics  
U. Kitakyushu, Kyushutech, Kumamoto, Miyazaki, Hiroshima City
Background and related programs in Waseda University

Industrial needs
- Crucial needs of professional engineers in IoT, BigData and AI
- Difficulty in utilizing data and leading data-driven innovation

Vision of Japanese governmennt
- Society 5.0: super smart society
- 4th industrial evolution

International situations
- Highly technology competitive environments
- Global human resource markets

Graduates and post-doctors

Industrial engineers

D-Data: data scientists program
EDGE-NEXT: innovation and entrepreneurship program
enPiT-Pro Smart SE

Data Science Research and Education Center

WASEDA VISION 150
Educating global leaders
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: 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, capston projects (continuous collaboration)
- **Agile network**: Networking, nation-wide industry-academia collaboration

---

**Business and value**

**Innovation**

**Foundational technologies**

**Organization and society**

**Agile mind and Process**

**AI**

- Data analytics
- Feedback

**BigData**

- Data collection

**IoT**

- Service
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

Application

Architecture and quality engineering

Embedded and realtime system

Security, privacy and law

Information processing

Machine learning

Big data

Knowledge processing and NLP

Machine learning

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Human resources who will lead the creation of value through the provision of smart systems and services: Full-stack engineers with expertise (three types)

* Smart systems and services: Services that respond to specific and detailed needs, and systems that accommodate those services and deliver them efficiently

Prerequisites
- Applicants must pass an entrance test equivalent to the intermediate-level MCPC IoT technology certification exam (Students who are expected to pass will be admitted under the condition that they will take an introductory course)
- Actual work experience in information technology

Anticipated participants
Those who have a fundamental knowledge of information systems

Human resource model (1)
Professionals of embedded systems and IoT
Design and build IoT systems that combine sensors and cloud computing, with a focus on business and innovation

Human resource model (2)
System of systems and quality architects
Creating an integrated system out of a group of systems, performing multifaceted quality evaluations for systems including security, and making improvements through big data analysis

Completion requirements
- Knowledge level equivalent to the advanced-level MCPC IoT technology certification exam is evaluated at each subject category.
- Demonstrate the ability to create value with a course completion project

Human resource model (3)
Cloud business innovator
Make future predictions by applying AI to analyze big data, and design and verify business models that offer adaptive services via cloud computing
Industry-academia collaboration network (at the time of enPiT-Pro)

Using the nation-wide network
- Developed teaching materials will be made available for use in each region, and will be used to train working adults
- Further expand the university network during the grant period (Ritsumeikan University, etc.)

Kitakyushu region
- Already established the Kitakyushu consortium with companies in the electronics industry
- Already running a working adult re-education program through a consortium with Waseda University (implemented ahead of enPiT-Pro efforts)
- Promoting education, graduate school enrollment, and collaborative research to regional companies that are part of the consortium

Waseda University (Kitakyushu Campus)
Kyushu University

Kansai region
- Osaka University
- Nara Institute of Science and Technology
- Ritsumeikan University (participating school)

Corporate outreach
- Acquire participants by cooperating with companies from the initial stage of developing teaching materials
- Gain trust from companies by designing courses that meet actual needs and with high-quality teaching contents
- Promote strong cooperation that leads to collaborative research with local industries and companies in each region, and link it to graduate school enrollment
- Proactively conduct PR activities for online teaching materials

Corporate partners (Over 5,000 partners including member companies)
Toshiba; Fujitsu; NEC; Hitachi; e-Seikatsu; Yahoo; Whole Brain Architecture Initiative; Densco; Hatax; 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
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• Practical features in Smart SE
  • Comprehensive program sets
  • Quality assurance
  • Feedback loop of education and research
• Related activities in IEEE-CS PEAB
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
   • Review of entire program based on reference frameworks

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
MOOC and on-demand lectures

JMOOC/gacco
- 13 lecture courses
- 20,000-30,000 learners/year
- In Japanese

edX
- 1 lecturer
- 2,000-3,000 learners/year
- In English
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

https://smartse.jp/information/2019/1105191102842/
## Comprehensive program sets

<table>
<thead>
<tr>
<th></th>
<th>Regular</th>
<th>JMOOC/gacco</th>
<th>edX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture courses</strong></td>
<td>15 courses and 2 projects</td>
<td>13 courses</td>
<td>1 course</td>
</tr>
<tr>
<td><strong>Learning methods</strong></td>
<td>Live-stream, on-demand, assembly format</td>
<td>On-demand only, no exercise</td>
<td>On-demand only, no exercise</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>6 hours/week</td>
<td>3 hours/week</td>
<td>3-5 hours/week</td>
</tr>
<tr>
<td><strong>Course periods</strong></td>
<td>6 months</td>
<td>3 months</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>30 learners</td>
<td>No limit</td>
<td>No limit</td>
</tr>
</tbody>
</table>
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.

https://wasedaneo.jp/1692/
https://www.wasecom.jp/article/1294
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, …

Positioning different education/training programs

[ Skill and competency levels]

- SmartSE
- Another program
- Target

[ Skill and competency classification]
Research: Automated course mapping by NLP and machine learning

Input

Course materials (PDF and Power Point)

iCD: Reference framework

Output

Term extraction

Automated mapping

(i) Embeddings

(A) Bag of words
(B) Word2Vec
(C) Sentence BERT

(ii) Automated determination

(A) Cosine similarity
(B) Random forest

Mapping result based on frameworks

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
i. Embeddings

**Input**

- **Text and slides**
  - "AI, BD, IoT are related …"
  - [A1, BD, IoT, are, related, …]
  - (A) BoW
    - [0 0 0 1 0 1 1 0 0 1 ...]
  - (B) Word2Vec
    - [[-0.187 -0.003 0.314
      0.147 0.051
      -0.399 0.183 0.152],
      [0.046 -0.071
      0.092 -0.057 0.057 -0.047]]
  - (c) Sentence BERT
    - [-0.051 0.068 ... 0.083 -0.215
      0.097 ....... 0.004
      ...
      ...
      0.046 ....... -0.071
      0.092 -0.057 ... 0.057 -0.047]

**Sentence extraction**

**Tokenization**

- or
- Average
  - [[-0.126 0.220 ... 0.104
    0.127 ....... 0.004
    -0.322 0.108 ... 0.032],
    [0.046 -0.071
    0.092 -0.057 0.057 -0.047]]

"Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract

Smart Systems and Services innovative professional Education program
ii. Automated determination of relation

(A) Cosine similarity

(B) Random forest

List of skills and competencies

Lecture courses

0.92345

0.65689

Training data

Text and slides

Objective

Feature vector

Multi-label

Manual mapping results

Training

Predictor

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
Experimental evaluation

- Targeting 30+ slide sets
- In terms of F-measure, combination of sentence distributed representation and supervised learning worked best.
- Need more improvement for practical usage

<table>
<thead>
<tr>
<th></th>
<th>Cosine similarity</th>
<th>Supervised learning (BoW)</th>
<th>Supervised learning (distributed representation)</th>
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<tbody>
<tr>
<td>Precision</td>
<td>0.313</td>
<td>0.545</td>
<td>0.706</td>
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<tr>
<td>Recall</td>
<td>0.417</td>
<td>0.240</td>
<td>0.480</td>
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<tr>
<td>F-value</td>
<td>0.357</td>
<td>0.333</td>
<td>0.571</td>
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</table>

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
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
Agenda

- Smart SE in the era of DX and 60-year curriculum
- Practical features in Smart SE
  - Comprehensive program sets
  - Quality assurance
  - Feedback loop of education and research
- Related activities in IEEE-CS PEAB
In ISO/IEC 17024 and ISO/IEC 24773-1, Competence and competency are defined as:

Ability to apply knowledge and skills to achieve intended results.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Knowledge</th>
<th>Skill</th>
<th>Proficiency level</th>
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<tbody>
<tr>
<td>Competency 1</td>
<td>List of knowledge required to demonstrate competency 1</td>
<td>List of skills required to demonstrate competency 1</td>
<td>Proficiency description</td>
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<td>Competency 2</td>
<td>List of knowledge required to demonstrate competency 2</td>
<td>List of skills required to demonstrate competency 2</td>
<td>Proficiency description</td>
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ISO/IEC 24773-1: 2019
IEEE Computer Society PEAB - Professional & Educational Activities Board

- Vice President for Professional and Educational Activities: Hironori Washizaki
- Mission: Providing leadership in the Society for activities related to the professional activities of practitioners in computing disciplines
- SWEBOK V4 Evolution
  - Defining modern software engineering profession
  - Major release within 2022
- Curriculum Development and Accreditation Collaboration
  - Further development and related activities for CC2020, and related joint efforts including development of CS20XX
  - CSAB continues to operate the accreditation process
- Courses and Packages Development
  - Organizing existing training/education assets and certifications
  - Digitizing and developing training/education courses aligned with SWEBOK and other disciplines including Machine Learning
- Other BOKs and Adoption
  - Academia and industry adoption of SWEBOK
  - Further promotion and adoption of EITBOK

https://www.computer.org/volunteering/boards-and-committees/professional-educational-activities
Plan of SWEBOK evolution

  - Guiding learners, researchers and practitioners to have common understanding on “generally-accepted-knowledge” in SWE
  - Defining boundary of SWE and related disciplines
  - Providing foundations for certifications and educational curriculum

- SWEBOK Guide history
  - 1998 started by IEEE CS/ACM

- SWEBOK Guide V3: 15 Knowledge area (KA)
  - Software Requirements, Software Design, Software Construction, Software Testing
  - Software Maintenance, Configuration Management, Engineering Management, Engineering Process
  - Engineering Economics, Software Quality, Engineering Methods, Professional Practices
SWEBOK V3 → V4

- Defining modern software engineering profession
- Incorporating Agile into most of knowledge areas
Summary

• Smart SE: Recurrent Education Program of IoT and AI for Business
  • DX and 60-year curriculum
  • Comprehensive program sets: MOOC and PBL
  • Quality assurance: course evaluation and mapping on reference frameworks
  • Feedback loop of education and research
• Related activities in IEEE-CS PEAB
  • SWEBOK evolution
  • Curriculum Development and Accreditation Collaboration
  • Courses and Packages Development
Further information

- Smart SE: [https://smartse.jp/](https://smartse.jp/)  [https://www.waseda.jp/inst/cds/]