An Innovative Approach in Developing Standard Professionals Involving Graduate Software Engineering Students in Implementing and Improving International Standards

Claude Y. Laporte, Rory V. O’Connor, Luis Hernán García Paucar, Bruel Gerançon

Presented by Professor Claude Y. Laporte, Eng., Ph.D. Project Editor of ISO/IEC 29110 Standard for Very Small Entities

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Content

• Introduction
• The Software Quality Assurance (SQA) Course of ÉTS
• An ISO standard, developed specifically for very small organisations, used to teach SQA at ÉTS
• Examples of the involvement of students in the implementation and improvement of standards
  – Canada, Ireland, Peru and Haiti
... studies have shown that software specialists spend about **40 to 50 percent** of their time on **avoidable rework** rather than on what they call value-added work, which is basically work that’s done right the first time ...
Laws of Nature

**Hooke’s Law**
\[ \sigma = E \cdot \varepsilon \]

**Newton’s Law**
\[ x(t) = \frac{1}{2}a \cdot t^2 + v_0 \cdot t + x_0 \]

**Boyle-Mariotte’s Law**
\[ p_1 x V_1 = p_2 x V_2 \]

**Curie’s Law**
\[ E = -\vec{\mu} \cdot \vec{B} \]

**Gravitational Law**
\[ \vec{F}_{A \rightarrow B} = -G \frac{M_A M_B}{AB^2} \vec{u}_{AB} \]

**Coulomb’s Law**
\[ F_{12} = \frac{q_1 q_2}{4\pi \varepsilon_0} \frac{r_2 - r_1}{|r_2 - r_1|^3} \]

**Refraction Law**
\[ \eta_1 \cdot \sin(\theta_1) = \eta_2 \cdot \sin(\theta_2) \]
Standards - A ‘Must’ in the Absence of Software Engineering Laws of Nature

‘Set of mandatory requirements established by consensus and maintained by a recognized body to prescribe a disciplined uniform approach or specify a product, that is, mandatory conventions and practices.’ (ISO/IEC/IEEE 24765)

www.computer.org/sevocab
Software Quality Assurance (SQA)

- A set of activities that define and assess the adequacy of software processes to provide evidence that establishes confidence that the software processes are appropriate for and produce software products of suitable quality for their intended purposes.

In Software Engineering, SQA is the neglected child!
Software Defect Injection

Defects (%)

System Development Phase

(Selby, 2007)
Software Defect Detected when Injected in Same Phase

Defects Detected / Defects Injected (%)
Over 7,600 students, 161 professors, 25 general senior lecturers.

About 2,400 paid industrial internships in over 800 companies each year (about 11,000 $ per internship)

Undergraduate Programs
- Software Engineering
- IT Engineering
- Construction Engineering
- Production Engineering
- Electrical Engineering
- Mechanical Engineering
- Logistics and Operations Engineering

Graduate Programs
- Software Engineering
- Information Technology
- Other programs

700 students
21 Professors in the department have a mean industrial experience of 10 years

www.etsmtl.ca
Software Quality Assurance - Lectures

Thirteen 3-Hour Lectures

1. **Introduction** (e.g. Business models, error, defect (not ‘bug’), failure)
2. **Quality Culture** (e.g. Software Engineering Code of Ethics, Cost of Quality)
3. **Quality Requirements** (e.g. Definition of software quality requirements)
4. **Standards and Models** (e.g. ISO 29110 for Very Small Entities (VSEs))
5. **Software Reviews** (e.g. Personal review, desk-check review (peer review))
6. **Software Audits** (e.g. Audit process, corrective actions)
7. **Verification and Validation** (Doing the right thing vs. doing things right)
8. **Configuration Management** (e.g. Identification, control, status, changes)
9. **Policies, Processes, and Procedures** (e.g. Process notation, assessment, improvement)
10. **Measurement** (e.g. Implementation of measurement, human factors)
11. **Risk Management** (e.g. Selection of practices, human factors)
12. **Supplier Management** (e.g. Supplier contract, contract review)
13. **Software Quality Assurance Plan**

Tests are covered in another course at ETS
Standards Presented and Used in the SQA course

• The author has developed an agreement with the Standards Council of Canada (SCC).
  – All registered SQA students can download, at no cost, ISO standards selected by the professor from the SCC website.
  – Standards are available in ‘read-only’ format

• Students at the ÉTS have access to the full content of the IEEE electronic library (in printable format)
  – All IEEE standards
  – All ISO/IEC/IEEE standards
Standards Presented in the SQA course

- **ISO/IEC/IEEE 24765** (Systems and software engineering - Vocabulary)
- **ISO/IEC/IEEE 12207** (Systems and software engineering - Software life cycle processes)
- **ISO/IEC 25000** (Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE)
- **ISO/IEC/IEEE 16085** (Systems and software engineering - Life cycle processes - Risk management)
- **ISO 9001** (Quality management systems - Requirements)
- **ISO/IEC 29110** (Systems and software engineering - Life cycle profiles for Very Small Entities (i.e. enterprises, organisations having up to 25 people))
- **ISO/IEC 90003** (Software engineering - Guidelines for the application of ISO 9001:2000 to computer software)
- **ISO/IEC/IEEE 15939** (Systems and software engineering - Measurement process)
- **ISO/IEC/IEEE 15289** (Systems and software engineering - Content of life cycle information products (documentation))
Software Quality Assurance
Textbooks

• Software engineering standards are presented in our textbooks

In French (Published in 2011)

L’assurance qualité logicielle 1
concepts de base

Claude Y. Laporte
Alain April

400 pages

L’assurance qualité logicielle 2
processus de support

Claude Y. Laporte
Alain April

386 pages

In English (Winter 2015)

Software Quality Assurance

CLAUDE Y LAPORTE
Ecole de technologie supérieure

ALAIN APRIL
Ecole de technologie supérieure

FIRST EDITION

Over 600 pages
Size of Enterprises

• European Union
  – 92% are micro enterprises (less than 10 employees)
• Micro enterprises account for 70% to 90% of enterprises in OECD* countries (about 57% in USA)
• Greater Montréal Area - Software Enterprises.

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>Number of Software Enterprises</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 25</td>
<td>540</td>
<td>78 %</td>
</tr>
<tr>
<td>25 to 100</td>
<td>127</td>
<td>18 %</td>
</tr>
<tr>
<td>Over 100</td>
<td>26</td>
<td>4 %</td>
</tr>
</tbody>
</table>

About 50% of enterprises have less than 10 employees
Source: Montreal International, 2006

* OECD: Organisation for Economic Co-operation and Development
ISO Working Group 24

Sub committee (SC) 7

Working Group (WG) 24

Joint Committee

Standardization of processes, supporting tools and supporting technologies for the engineering of software products and systems.
Spectrum of Development Approaches

Waterfall
- Few risks, sequential
- Late integration and testing

High Ceremony
- Iterative
- Little documentation
- Light process
- Risk-driven
- Continuous Integration and testing
- Well-documented
- Traceability
- CCB

Low Ceremony
- XP, Scrum, Adaptive Development
- CMM
- CMMI

ISO 29110

ISO/IEC 29110 Standards and Guides
For Very Small Entities (VSEs)

- **Entry** - Targets VSEs typically developing *6 person-month* projects or *start-ups*;
- **Basic** - Targets VSEs developing only *one project at a time*;
- **Intermediate** – Targets VSEs developing *multiple projects* within the organizational context;
- **Advanced** – Targets VSEs which want to *sustain and grow* as an independent competitive software development business.

**VSEs** = *Very Small Entities* are enterprises, projects or departments having up to *25* people. Standards and Guides for VSEs in systems and/or software engineering.
ISO/IEC 29110
Management and Engineering Guide

Software Implementation Process
- Initiation
- Analysis
- Design
- Construction
- Integration and tests
- Delivery

Customer
- Statement of Work
- Software Configuration

Project Management Process
- Planning
- Evaluation
- Execution
- Closure

Organizational Management

Available at no cost from ISO at: http://standards.iso.org/ittf/PubliclyAvailableStandards/index.html
Available in English, French, Spanish, Portuguese

Adapted from (Varkoi 2010)
Software Quality Assurance
and Process Improvement Courses
at the Graduate Level

• For the SQA course, the same topics are covered at the graduate level
• Instead of a specific team project determined by the professor, graduate students, in team of 2-4 students, do a 13-week project, in a real organisation (e.g. enterprise, government, not-for-profit)
  – Identify an area for improvement
  – Obtain approval of a manager of the organisation
  – Implement, in a small pilot project, ISO 29110
  – Review results with management
  – Provide recommendations for the next steps to management
  – Provide recommendations about ISO 29110 to the professor
• The Process Improvement course has a similar project in a real organisation
• After the course, a few students decided to continue the implementation of ISO 29110 in other organisations
• Offers a range of services in the production of hydro-electric, wind, geothermal, solar or biomass-related energy.
• Company established 10 years ago,
• Over 500 employees spread over 10 offices in Canada,

<table>
<thead>
<tr>
<th>Duration of project</th>
<th>Small Project</th>
<th>Medium project</th>
<th>Large project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 2 months</td>
<td>Between 2 and 8 months</td>
<td>More than 8 months</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size of team</th>
<th>Small Project</th>
<th>Medium project</th>
<th>Large project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal or less than 4 people</td>
<td>Between 4 and 8 people</td>
<td>More than 8 people</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of engineering specialties involved</th>
<th>Small Project</th>
<th>Medium project</th>
<th>Large project</th>
</tr>
</thead>
<tbody>
<tr>
<td>One specialty</td>
<td>More than one specialty</td>
<td>Many specialties</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering fees</th>
<th>Small Project</th>
<th>Medium project</th>
<th>Large project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 5,000$ and 70,000$</td>
<td>Between 50,000$ and 350,000$</td>
<td>Over 350,000$</td>
<td></td>
</tr>
</tbody>
</table>

• Used ISO 29110 to document their small/medium project processes

Adapted from (Laporte et col. 2013)
Pilot Project in a Large Engineering Firm

**Large Engineering Company**

- Cost analysis using the ISO method to evaluate the *Economic Benefits of Standards*

**Value chain**

**Costs and Benefits**

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost to implement and maintain</strong></td>
<td>$59 600$</td>
<td>$50 100$</td>
<td>$50 100$</td>
<td>$159 800$</td>
</tr>
<tr>
<td><strong>Net Benefits</strong></td>
<td>$255 500$</td>
<td>$265 000$</td>
<td>$265 000$</td>
<td>$785 500$</td>
</tr>
</tbody>
</table>

Adapted from (Laporte et al. 2013)
Pilot Project in an IT Start-Up

- Start-up of 2 people
- Project of 990.5 Hours

<table>
<thead>
<tr>
<th>Phase of development cycle</th>
<th>Prevention (Hours)</th>
<th>Execution (Hours)</th>
<th>Review (Hours)</th>
<th>Rework (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of the work environment</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project management and Project progress</td>
<td></td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deployment</td>
<td>8,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Project Plan</td>
<td>35</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Software Specification and Prototyping</td>
<td>199,5</td>
<td>7</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Development of the Architecture</td>
<td>42.5</td>
<td>1.5</td>
<td>3,5</td>
<td></td>
</tr>
<tr>
<td>Construction (Prototype and code)</td>
<td>361</td>
<td>47</td>
<td>96,5</td>
<td></td>
</tr>
<tr>
<td>Development of Test Plan</td>
<td>12.5</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Development of product and User guide</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Project closure</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>89</td>
<td>716</td>
<td>60.5</td>
<td>125</td>
</tr>
</tbody>
</table>

- Rework of 12.6% (125 hours/990.5 hours)

Adapted from (Laporte et al 2014)
Start-up in Transportation

- Public transportation customers often require a CMMI® maturity level for system and sub-system suppliers.

- In 2012, the VSE was composed of 4 people (7 presently).
  - Implementing the CMMI® Level 2 Process Areas was too demanding at that time.

- Strategy
  - Implement the draft version of Systems Engineering ISO/IEC 29110 Basic profile as a foundation
  - Perform a gap analysis between CMMI level 2 and the SE Basic Profile
  - Implement the practices needed for a CMMI level 2 assessment.

- Graduate student made many important comments to draft version of ISO/IEC 29110 for Systems Engineering

www.csintrans.com  Adapted from (Tremblay et al 2014)
Deployment Packages
Paquetes de Despliegue para el Perfil Básico

• Deployment Packages (DPs) are used to accelerate the implementation of ISO/IEC 29110

• Translated and improved by graduate students of Universidad Peruana de Ciencias Aplicadas (Perú) and used in VSEs in Latin America

• DPs have been used in a Peruvian VSE which was granted an ISO/IEC 29110 certificate of conformity by Brazilian auditors

Available at no cost in English, French and Spanish.
ISO/IEC 29110 in Haiti

• A student of the Graduate Program in software engineering of Montréal has done his project on the implementation of ISO/IEC 29110 in two VSEs of Haiti

• He returned to Haiti, as a software engineering professor, at the Institut Universitaire Quisqueya-Amérique (INUQUA)

• Over 14 software VSEs of Haiti have been evaluated against ISO/IEC 29110 as part of a software quality assurance course
  – Fourteen teams of students made these evaluations.

• For the summer session of 2014, at least 80 students will evaluate the development processes of other VSEs using the ISO/IEC 29110 standard.

http://www.inuka.edu.ht/
Evaluating Sentiment Towards ISO/IEC 29110 in Ireland

• Qualitative study was conducted in 10 software product VSEs
  – Were in start-up phase or recently formed (< 24 months)

• Software lifecycle standard is a low priority issue
  – Low to no demand for standards compliance from clients
  – The perception that the software lifecycle standards are designed for the big companies rather than for VSEs
  – The view of standards as a ‘sales tool’ only

• A potentially significant way to develop standards professionals
  – Having professional graduate students involved in the application and improvement of international standards in VSEs
Countries Teaching ISO/IEC 29110

- Argentina
- Belgium
- Brazil
- Canada
- Czech Republic
- Finland
- Germany
- Haiti
- Ireland
- Japan
- Mexico
- Peru
- Thailand
- Uruguay
Conclusion

- Software engineering, being a discipline with no laws of nature as its foundation, need students to learn and apply standards
- Students can learn, apply and recommend improvements to software engineering (SW) standards
  - If SW standards are understandable and usable by them
  - Freely available documents are highly desirable in academia
- A large majority of organisations worldwide are very small
- ISO/IEC 29110 has been specifically developed for organisations having up to 25 people
- A few countries have successfully taught and used ISO/IEC 29110 in real organisations

A Systems Engineering ISO/IEC TR 29110 is now available from ISO
Contact Information

- Claude Y Laporte
  - Voice: + 1 514 396 8956
  - E-Mail: Claude.Y.Laporte@etsmtl.ca
  - Web: http://profs.etsmtl.ca/claporte/English/index.html

- Public site of WG 24
  - Free access to Deployment Packages, presentation material and articles:
    - http://profs.logti.etsmtl.ca/claporte/English/VSE/index.html