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From the SelectedWorks of Cécile Péraire

Fall December 6, 2013

A Step Forward in Software Engineering Education: Introducing the SEMAT Essence Framework

Cécile Péraire, Carnegie Mellon University

Available at: https://works.bepress.com/cecile_peraire/2/
A Step Forward in Software Engineering Education:
Introducing the SEMAT Essence Framework

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Carnegie Mellon University - Silicon Valley Campus
Evidence-Based Software Engineering Group

With the Participation of
Dr. Carlos Zapata
Universidad Nacional de Colombia
Who am I?

- Assistant Professor at CMU SV
- Co-Lead SEMAT Education Area
- Areas of Interest
  - Agile, Lean & Disciplined Software Development
  - Requirements Engineering, Empirical Studies

Previous Life:

- Ph.D. in C.S. (Software Testing) from EPFL
- Postdoc at SRI & HP
- Various experiences at Rational & IBM
  - Consultant, Project/Program Manager, Methodologist
  - Contributed to RUP and IBM's internal methods
Agenda

• Challenges in SE Education
• What is SEMAT? What is Essence?
• How does the Essence Kernel Work?
• World Tour of SEMAT Educational Activities
  – Carnegie Mellon University
  – Universidad Nacional de Colombia
• SEMAT Vision for Education
Fact or Fiction?

The Industry is driving software engineering innovation with Academia lagging behind.
Evolution of Software Methods

Source: Kennaley, SDLC 3.0.
Additions: SAFe & DAD &

Legend: Method originated from Academia: ★
Out of the 40 methods which made it to the chart a minority (about 15%) originated from Academia or was significantly influenced by Academia. Among this minority, none are from Agile or Lean lineage.
Evolution of Software Methods

32 methods emerged in the last 20 years

→ 1.6 new methods per year
Challenges in SE Education

• Select Method(s) to Teach
  – Based on what criteria?
    • Adoption rate
    • Effectiveness
    • Coverage
    • Etc.

• Compare Methods
Challenges in SE Education

• Select Terminology

• Address Various Needs of Students

I want to create a startup

I want to join an international corporation
Challenges in SE Education

- Keep courses cutting edge with minimum waste/rework
- Conduct research adding value to our courses and to the industry
Stop teaching methods; Start teaching practices!

Methods are composed out of a buffet of generally accepted practices

“Teams are puzzling out the mix of methodologies and combining them to fit within their organizational realities, blending Agile and non-Agile techniques and practices to create a hybrid methodology”

D. West, T. Grant, 2010
Teach practices in context

Practices are only “GOOD” in context

Octopus: “All projects are different!”

Source: Philippe Kruchten, The Frog & the Octopus

Other authors advocating about context: B. Boehm, A. Cockburn & S. Ambler
Some Ideas

Teach the essence of methods

Anchor SE courses in common grounds

Source: Philippe Kruchten, The Frog & the Octopus
Some Ideas

• Conduct research around:
  – The essence of methods / software engineering
  – Practices (definition & validation in context)
Agenda

• Challenges in SE Education
• **What is SEMAT? What is Essence?**
• How does the Essence Kernel Work?
• World Tour of SEMAT Education Activities
• SEMAT Vision for Education
What is SEMAT?

**SEMAT**: Software Engineering Method and Theory

**Founders**: Ivar Jacobson, Bertrand Meyer, Richard Soley

**Vision**: Re-found software engineering as a rigorous discipline based on a general theory of software engineering and a unifying process framework

**Creation**: 2009

www.semat.org
What is Essence?

Essence Method Architecture

Methods
- Custom Method M
- Custom Method N

Practices

Kernel
- Essence Kernel

Language
- Essence Language

OMG
Essence Language & Kernel became OMG beta standard in 2013

State-based Progress Monitoring & Goal-driven Project Steering
Essence Kernel Alphas

Kernel Alphas

Requirements
- Conceived
- Bounded
- Coherent
- Acceptable
- Addressed
- Fulfilled

Alpha States Checklists

Endeavor
- Work
  - Team
    - Way of Working

Solution
- Requirements
  - Software System
    - Stakeholder
      - Opportunity
        - Customer
          - Identifies

LACREST MEDELLÍN 2013
Requirements Engineering & Software Testing
LATIN AMERICAN CONGRESS

Carnegie Mellon University
Silicon Valley
Agenda

- Challenges in SE Education
- What is SEMAT? What is Essence?
- How does the Essence Kernel Work?
- World Tour of SEMAT Educational Activities
- SEMAT Vision for Education
How does the Essence Kernel Work?

Step Back & Look at Project Holistically

- Act on Work Items
- Monitor Progress
- Decide How to Reach Goals (Work Items)
- Set Project Direction & Goals

Opportunity

Work

Stakeholders

Requirements

Way of Working

Team

Software System

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How does the Essence Kernel Work?

1. **Step Back & Look at Project Holistically**
2. **Monitor Progress**
3. **Act on Work Items**
4. **Decide How to Reach Goals (Work Items)**
5. **Set Project Direction & Goals**

- **Current State**
  - **Requirements**
    - **Conceived**
      - The need for a new system is clear
      - Users are identified
      - Initial sponsors are identified
    - 1/6
    - **Bounded**
      - The purpose and extent of the system are agreed
      - Success criteria are clear
      - Mechanisms for handling requirements are agreed
      - Constraints and assumptions identified
    - 2/6
    - **Coherent**
      - The big picture is clear and shared by all involved
      - Important usage scenarios explained
      - Priorities are clear
      - Conflicts are addressed
      - Impact is understood
    - 3/6
    - **Acceptable**
      - Requirements describe a solution acceptable to the stakeholders
      - The rate of change to agreed requirements is low
      - Value is clear
    - 4/6
    - **Addressed**
      - Enough requirements are implemented for the system to be acceptable
      - Stakeholders agree the system is worth making operational
    - 5/6
    - **Fulfilled**
      - The system fully satisfies the requirements and has the need
      - There are no outstanding requirements items preventing completion
    - 6/6
How does the Essence Kernel Work?

- **Step Back & Look at Project Holistically**
- **Act on Work Items**
- **Monitor Progress**
- **Set Project Direction & Goals**

**Current State**
- Requirements
  - Conceived
    - The need for a new system is clear
    - Users are identified
    - Initial sponsors are identified
  - Bounded
    - The purpose and extent of the system are agreed
    - Success criteria are clear
    - Mechanisms for handling requirements are agreed
    - Constraints and assumptions identified
  - Goals

**Target State**
- Requirements
  - Conceived
  - Bounded
  - Goals
  - Coherent
    - The big picture is clear and shared by all involved
    - Important usage scenarios explained
    - Priorities are clear
    - Conflicts are addressed
    - Impact is understood
  - Acceptable
    - Requirements describe a solution acceptable to the stakeholders
    - The rate of change to agreed requirements is low
    - Value is clear
  - Addressed
    - Enough requirements are implemented for the system to be acceptable
    - Stakeholders agree the system is worth making operational
  - Fulfilled
    - The system fully satisfies the requirements and the need
    - There are no outstanding requirements items preventing completion

**Opportunity**
- Stakeholders
- Requirements
- Software System
- Team
- Work

**Set Project Direction & Goals**

Carnegie Mellon University
Silicon Valley
How does the Essence Kernel Work?

Step Back & Look at Project Holistically

Act on Work Items

Monitor Progress

Decide How to Reach Goals (Work Items)

Set Project Direction & Goals

Current State

Requirements
- Conceived
  - The need for a new system is clear
  - Users are identified
  - Initial sponsors are identified

Work Items:
- Define Project Scope
- Clarify Success Criteria

Target State

Requirements
- Bounded
  - The purpose and extent of the system are agreed
  - Success criteria are clear
  - Mechanisms for handling requirements are agreed
  - Constraints and assumptions identified

Opportunity
Work
Stakeholders
Requirements
Software System
Way of Working
Team
Conceived
Bounded
Opportunity
0
1
2
3
4
5
6
Current State
Target State
How does the Essence Kernel Work?

1. Decide How to Reach Goals (Work Items)
2. Set Project Direction & Goals
3. Act on Work Items
4. Monitor Progress
5. Step Back & Look at Project Holistically

Work Items:
- Define Project Scope
- Clarify Success Criteria
- ...
- ...
- ...
- ...

Carnegie Mellon University
Silicon Valley
How does the Essence Kernel Work?

Step Back & Look at Project Holistically

Act on Work Items
Monitor Progress

Decide How to Reach Goals (Work Items)
Set Project Direction & Goals

Time has passed...
Agenda

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  - Carnegie Mellon University
  - Universidad Nacional de Colombia
- The SEMAT Vision for Education
World Tour of SEMAT Educational Activities

Universities and institutes members of the SEMAT Education Area and leveraging Essence in software engineering education (2013)
Field Study of Essence Kernel at CMU

Research Goal: Evaluate the effectiveness of Essence’s monitoring and steering approach provided by the kernel alphas and their states in the context of practicum graduate courses
**Field Study of Essence Kernel at CMU**

<table>
<thead>
<tr>
<th>Team Name</th>
<th>Industry Project</th>
<th>Team Size</th>
<th>Average Work Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Medium to high technical complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>15 week project - Each student works 20 hours per week</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distributed-1</td>
<td>Audio streams rendering for accessibility</td>
<td>3</td>
<td>10 years</td>
</tr>
<tr>
<td>Distributed-2</td>
<td>Access/preservation of electronic journals</td>
<td>4</td>
<td>6 years</td>
</tr>
<tr>
<td>Distributed-3</td>
<td>Survivable social network</td>
<td>4</td>
<td>8 years</td>
</tr>
<tr>
<td><strong>12 week project - Each student works 20 hours per week</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-located-1</td>
<td>Electric vehicle fleet management</td>
<td>2</td>
<td>3 years</td>
</tr>
<tr>
<td>Co-located-2</td>
<td>Sonification of financial trading</td>
<td>4</td>
<td>3 years</td>
</tr>
<tr>
<td>Co-located-3</td>
<td>Mobile performance testing</td>
<td>3</td>
<td>4 years</td>
</tr>
<tr>
<td>Co-located-4</td>
<td>Virtual sensors definition &amp; management</td>
<td>5</td>
<td>5 years</td>
</tr>
</tbody>
</table>

Teams are self-organizing - No constraints on development method - Iterative lifecycle
Field Study of Essence Kernel at CMU

Physical Strips (versus Cards)
One Strip per Alpha

Digital Essence Board
**Field Study of Essence Kernel at CMU**

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**Essence Log**

*Updated weekly (½ hour session)*

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**Final Survey**

- What did you like the most about Essence?
- What did you like the least about Essence?
- Was following Essence worth your time? *(Please explain why or why not)*
- Would you use Essence on your next project? *(Please explain why or why not)*
- ...

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<table>
<thead>
<tr>
<th>Date:</th>
<th>Iteration:</th>
<th>Week:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alpha</strong></td>
<td><strong>Current State</strong></td>
<td><strong>Target State</strong></td>
</tr>
<tr>
<td>Stakeholders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunity</td>
<td></td>
<td></td>
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<tr>
<td>Requirements</td>
<td></td>
<td></td>
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<tr>
<td>Soft. System</td>
<td></td>
<td></td>
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<tr>
<td>Team</td>
<td></td>
<td></td>
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<tr>
<td>Way of Working</td>
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<tr>
<td>Work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Research Questions

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the approach provide value to the project team?</td>
</tr>
<tr>
<td>How does it provide value to the project team?</td>
</tr>
<tr>
<td>When in the project lifecycle does it add value?</td>
</tr>
<tr>
<td>What are the limits of the approach?</td>
</tr>
</tbody>
</table>
Research Question: Does the approach provide value to the project team?

Survey Question: Was following the Essence approach worth your time?
- Yes: 90%
- No: 10%

Survey Question: Would you use Essence on your next project?
- Yes: 80%
- No: 20%
Research Question: How does the approach provide value to the project team?

Value comes primarily from team discussions

Let’s take a closer look...
Field Study of Essence Kernel at CMU

Step Back & Look at Project Holistically

Quotes from CMU Students:

“Essence gives us a chance to back up and look at the project as a whole, from the birds point of view.”

“Essence provides a structured way of thinking about critical aspects of the project. Without Essence, our team could have overlooked some of these aspects.”

Structure for Retrospectives
Field Study of Essence Kernel at CMU

Quotes from CMU Students:

“The alphas seem to be exactly the right areas to monitor to promote project success.”

“Essence is great for team reflection & risk management.”

**RISK: Opportunity & Requirements defined without proper stakeholders involvement**

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Stakeholders</th>
<th>Stakeholders</th>
<th>Stakeholders</th>
<th>Stakeholders</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognized</td>
<td>Represented</td>
<td>Involved</td>
<td>In Agreement</td>
<td>Satisfied for Deployment</td>
<td>Satisfied in Use</td>
</tr>
<tr>
<td>- Stakeholders have been identified</td>
<td>- Stakeholder representatives appointed</td>
<td>- Stakeholder representatives carry out responsibilities</td>
<td>- Stakeholder representatives agree their input is valued and respected by the team</td>
<td>- System has met or exceed minimal stakeholder expectations</td>
<td></td>
</tr>
<tr>
<td>- Stakeholders have been identified</td>
<td>- Stakeholder representatives agreed to take on responsibilities &amp; authorized</td>
<td>- Stakeholder representatives provide feedback &amp; take part in decisions in timely way</td>
<td>- Stakeholder representatives agree with how different priorities balance</td>
<td>- Stakeholder needs and expectations are being met</td>
<td></td>
</tr>
<tr>
<td>- Responsibilities of stakeholder representatives defined</td>
<td>- Collaboration approach agreed</td>
<td>- Stakeholder representatives promptly communicate to stakeholder group</td>
<td>- Stakeholder representatives have agreed upon minimal expectations for deployment</td>
<td>- Stakeholder representatives confirm system ready for deployment</td>
<td></td>
</tr>
<tr>
<td>1/6</td>
<td>2/6</td>
<td>3/6</td>
<td>4/6</td>
<td>5/6</td>
<td>6/6</td>
</tr>
</tbody>
</table>
Field Study of Essence Kernel at CMU

Quotes from CMU Students:
“Essence gives us structure and direction.”
“Essence is useful, as it gives you an agenda or checklist based on various dimensions.”

Current State
- Stakeholders
  - Recognized
  - Represented
  - Involved

Target State
- Stakeholders
  - Represented
  - Involved

Stakeholders
- Opportunity
- Stakeholders
- Requirements
- Software System
- Team
- Way of Working

Mechanism for Project Steering

Opportunity
- Represented
- Recognized

Recognized
- Represented
- Involved

Recognized
- Represented
- In Agreement

Involved
- Stakeholder representatives carry out responsibilities
- Stakeholder representatives provide feedback & take part in decisions in timely way
- Stakeholder representatives agree with how different priorities balance
- Stakeholder representatives have agreed upon minimal expectations for deployment

In Agreement
- Stakeholder representatives provide feedback on system from their stakeholder group perspective
- Stakeholder representatives confirm system ready for deployment

In Agreement
- Satisfied for Deployment
  - System has met or exceed minimal stakeholder expectations
  - Stakeholder needs and expectations are being met

Satisfied in Use

Goals
- Stakeholders
  - Recognized
  - Represented
  - Involved

Field Study of Essence Kernel at CMU

Decide How to Reach Goals (Work Items)

Quote from CMU Student:
“I will use Essence on my next project, especially with a team that is not used to the same software engineering process. In that case Essence is a backdrop at the basis of the communication about all the considerations for the success of the project.”

Opportunity
Stakeholders
Requirements
Way of Working
Work
Current State
Target State
Non-prescriptive & Method Agnostic

Work Items:
- ...
- ...
- ...

Up to the team!
The Essence kernel provides a structure and mechanism for:

- Progress monitoring
- Retrospectives
- Risk management
- Project steering

In a holistic, simple, lightweight, non-prescriptive and method-agnostic fashion
Field Study of Essence Kernel at CMU

Research Question:
When in the project lifecycle does the approach add value?

Alpha State Progression for Team Co-located-3

Initial state progression is driven by Essence-generated work items
Field Study of Essence Kernel at CMU

Research Question: When in the project lifecycle does the approach add value?

Number of work items generated per week and leading to a higher project state

![Graph showing the number of work items generated per week and leading to a higher project state for different teams and an average.](image-url)
Research Question:
When in the project lifecycle does the approach add value?

Effectiveness is optimal during project initiation & decreases over time

Quote from CMU Student:
“Essence [Kernel] lost value once the project settled because we dead ended on a set of cards.”

Quote from Practicum Course Faculty:
“Compared to previous years, I see a much better early project organization with lot less floundering. I hope that we keep using Essence in the future. We should definitely keep it at the beginning of the projects.”
Field Study of Essence Kernel at CMU

Research Question:
When in the project lifecycle does the approach add value?

Most teams continue to perceive value throughout the lifecycle out of the retrospectives

Quote from CMU Student:
“Even though we are not generating new tasks, the SEMAT meetings remain useful as they give us the opportunity to reflect upon our project.”
Field Study of Essence Kernel at CMU

Research Question:
What are the limits of the approach?

By design, the Kernel is universal:
• Lifecycle-independent
  → Iterative development requires additional support
• Generally expressed at a project/release level
  → Lower level work requires additional support
    (like technical work done during an iteration)

Hence the work done during construction on iterative projects requires additional support
Research Question:
What are the limits of the approach?

Essence’s monitoring and steering approach provided by the kernel alphas and their states is optimum during project initiation and for monitoring and steering the work done at the project or release level. Beyond that, the approach’s value decreases as the inherent limits of the universal kernel are reached.
Field Study of Essence Kernel at CMU

How could we push the limits?

- Leverage practices on top of the Kernel

- Leverage other facets of the Kernel

- Extend or alter the Kernel definition
  - Is the Kernel truly universal?
  - Are there universal elements that are missing?
Field Study of Essence Kernel at CMU

Essence Value:
Team discussions based on holistic project view to achieve lightweight:

- Progress monitoring
- Retrospectives
- Risk management
- Project steering

Any Method
E.g. Scrum & XP

Essence Kernel
The Foundation
Main activities

- Modifications to current courses
- Proposal of a new course
- Game design and playing
- Tutorials in several events
• Current courses
  – Software project management
  – Requirements engineering
  – Software application design and construction

• Modifications to existing courses
  – Representation of the UNC-Method in the SEMAT kernel
  – Control of Endeavour health and progress with alpha cards
  – Risk control with the SEMAT kernel
Proposal of a new course:
- Name: “Software Engineering Methods and Theory”
- Syllabus
  - A. General Software Engineering Theory Introduction
    - A.1. Motivation
    - A.2. General problems about Software Engineering
    - A.3. Why we need a Software Engineering Theory?
  - B. Basic Elements of the Software Engineering Kernel
    - B.1. Alphas
    - B.2. Activity spaces
    - B.3. Methods and practices
    - B.4. Competencies
    - B.5. Work products
– Syllabus

• C. Advanced elements of the Software Engineering kernel
  • C.1. Patterns
  • C.2. Resources
  • C.3. Detail levels
  • C.4. Competency levels
  • C.5. Card representation
  • C.6. Separation of concerns
  • C.7. Kernel work tools

• D. Formal representation of the Software Engineering kernel
  • D.1. Introduction
  • D.2. Kernel metamodel
  • D.3. Kernel textual specification
  • D.4. Object diagrams and executable pre-conceptual schemas
• Game design and playing:
  – SemCards
  – MetricC
  – The software system alpha
  – The requirements alpha
  – Etc.
Step 1: A card with a description appears

Step 2: Player selects the element he/she thinks fits the card

Step 3: The system assigns points according to the answer
Step 4: After some turns, the system notifies the winner.
• MetricC
  – The game is based on Hasbro™’s *Mille Bornes*
  – It matches metrics and completion criteria with activity spaces
  – Four kinds of cards: attack, defense, metric, and completion criteria
  – The goal of the game is achieving three completion criteria by adding values to metrics
**Good practice**

**Activity Space:** Understand the requirements

**Discard a Metric**

**Enable a Completion Criterion**

- The initial set of stakeholders agrees that a system is to be produced

**Limit Metric**

**Completeness of description**

**Bad practice**

**Full Metric**

**Max Metric Value:** 10

**Metric**

**Activity Space:** Understand the requirements

**Related Completion Criterion:** The initial set of stakeholders agrees that a system is to be produced
• The software system alpha
  – Only available in Spanish
  – Players are team members whom need to “travel” across the states of a software system
  – Some situations arise for giving the possibility of advancing the states
  – The situations are described in terms of the SEMAT kernel elements (alphas, activity spaces, competencies, etc.)
  – The “retired” state is always a possibility of the game
• The requirements alpha
  – Only available in Spanish
  – Players are team members whom need to “travel” across the states of the requirements of a software system
  – “Guessing” the states belonging to certain alpha is one of the options for advancing the states
  – Some situations arise for giving the possibility of advancing the states
  – The situations are described in terms of the SEMAT kernel elements (alphas, activity spaces, competencies, etc.)
- Se terminó el que produce resultados, se están consiguiendo los resultados, el cliente aceptó el software resultante.
Essence-Powered SE Education at UniBz

Open Source Web-based Tool for SEMAT Kernel
http://sematacc.meteor.com

Course: Introduction to Management Engineering

Research question:
How intrinsic are SEMAT Essence Kernel elements for inexperienced students?

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Essence-Powered SE Education at KTH

Using the Essence Kernel at KTH in the context of an IT-Project course (2012-2013)

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Educational Activities under auspices of
The Jo'burg Centre for Software Engineering (JCSE)
In the School of Electrical and Information Engineering
At the University of the Witwatersrand
www.jcse.org.za

JCSE Courses & Workshops Leveraging Essence:

• ELEN 7044 - Software Engineering Principles and Methods
  Audience: Masters Students and/or Continuous Professional Development

• ELEN 7012 - Selected Topics in Software Engineering
  Audience: Masters Students and/or Continuous Professional Development

• Using SEMAT Essence for Project Health Check and Action Planning
  Workshop Audience: Practitioners in Industry

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Essence-Powered Education at MIPT

Anatoly Levenchuk

Essence for Systems Engineering

MIPT Courses leveraging Essence:

- Foundation of Systems Engineering (2013)
- Systems Engineering Thinking in Lifecycle Management (2014)
- Practices of Model-based Systems Engineering (2014)
Essence Education Material from IJI

Progress Poker | Lifecycle Layout
---|---
Chase the State | Milestone Mapping
Objective Go | Health Monitoring
Checkpoint Construction | And more......

http://www.ivarjacobson.com/alphastatecards/

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Agenda

• Challenges in SE Education
• What is SEMAT? What is Essence?
• How does the Essence Kernel Work?
• World Tour of SEMAT Educational Activities
• SEMAT Vision for Education
Courses are based on a generally accepted foundation scientifically validated
Students learn about generally accepted practices including measures of effectiveness in context.

Data help educators make informed decisions about what to teach.

Modularity facilitates course evolution; Courses are kept cutting edge with minimum waste/rework.
Students learn to compose methods out of (potentially tailored) practices based on project context.
Students are trained to become “generalizing specialists” enabling a smoother transition between:

- University and Industry
- Projects
- Organizations
- Positions
- Domains
A Step Forward
References


• Ivar Jacobson and all. The Essence of Software Engineering: Applying the SEMAT Kernel, Addison-Wesley, 2013.


• SEMAT Essence Kernel Tool, http://essence.sv.cmu.edu

• Semat.org
Gracias!

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Carlos Zapata - cmzapata@unal.edu.co