Big Data and Education: Education and Skills Development in Big Data and Data Intensive Science

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ISO/IEC SGBD Big Data Technologies Workshop
Part of ISO/IEC Big Data Study Group meeting
13-16 May 2014
Introduction to discussion on Education and Training for Big Data (or Data Intensive Science and Technologies)

• Horizon2020: Education and skills development for Research e-Infrastructure

• Data Science education programs development by universities
  – Big Data and Data Science – Not only Data Mining and Data Analytics
  – Examples Data Science / Data Intensive Science / Big Data curricula development

• Initiatives and developments in US and EU
  – HPC University in US

• Initiatives and developments at the University of Amsterdam (UvA)
  – Data Science Master program development
  – **EDISON Initiative to coordinate Data Science curriculum development**
Topics for Discussion

• Big Data divide and need for Professional Education and Training
  – Between scientific domains
  – Between IT and non-IT
  – Between countries

• How to share experience between universities that have already started development of Data Science programs?
  – What experience do we have on component technologies?
  – Existing instructional and educational concepts and technologies
    • Top down approach vs bottom up approach
    • Project based collaborative education

• Education and Training program development approaches
  – Targeting different communities and research domains
  – Technical vs non-technical vs subject domains
WP2014-2015 European research infrastructures (including e-Infrastructures)

- EINFRA-4-2014 – Pan-European High Performance Computing infrastructure and services
- EINFRA-5-2015 – Centres of Excellence for computing applications
  - … research in HPC applications; and addressing the skills gap in computational science
- INFRASUPP-3-2014 – Strengthening the human capital of research infrastructures
  - The skills and expertise specifically needed to construct, operate and use research infrastructures successfully therefore are not widely available
- INFRASUPP-4-2015 – New professions and skills for e-infrastructures
  - See next slide
INFRASUPP-4-2015 – New professions and skills for e-infrastructures

(1) Defining or updating university curricula for the e-infrastructure competences mentioned above, and promoting their adoption.

(2) Developing and executing training programmes (including for lifelong learning) for the above mentioned professionals working as part of a team of researchers or supporting research teams.

(3) Support the establishment of these professions as distinct professions from that of a researcher. Create a reference model which defines their competencies, supported by case studies and best practices relating to e-infrastructures skills, human resources management, support tools and related institutional practices. Develop alternatives means for recognising non-research contributions by research technologists and data scientists.

(4) Support networking and information sharing among already practicing e-infrastructure experts, research technologists, computation experts, data scientists and data librarians working in research institutes and in higher education.

(5) Awareness raising activities; establish and promote e-infrastructures community champions to advocate on new jobs and skills needs at schools, universities and scientific communities.
Data Science education programs development by universities

- Data Science programs in US and Europe – Info page
  - Indiana University (Prof. Geoffrey Fox)
  - San Diego Supercomputing Center (SDSC)
  - HPC University in US+
  - Many others
- Currently most of programs are refactored/derived from Data Mining and Analytics, Machine Learning, Business Analytics
  - Big Data and Data Science – Not only Data Mining and Data Analytics
  - Big Data require e-Infrastructure to support data processing, storing and management
- Examples Data Science / Data Intensive Science / Big Data curricula development
  - University of Stavanger (UiS) and Purdue University
  - University of Liverpool and Laureate Online Education
  - University of Amsterdam and Vrij Univ Amsterdam
- Numerous initiatives to provide training to non-IT community
  - Librarians, Data archivists, etc.
  - Data Intelligence 4 Librarians designed by 3TU.Datacentrum and DANS [http://dataintelligence.3tu.nl/en/home](http://dataintelligence.3tu.nl/en/home)
HPC University is a Virtual Organization whose membership is open to all organizations that would like to contribute to the preparation of current and future generations of HPC practitioners.

http://hpcuniversity.org/

- **XSEDE**, NCSA Blue Waters, Shodor Education Foundation, Inc., **Ohio Supercomputer Center**, San Diego Supercomputer, ACM SIGHPC, Cyprus Institute, Partnership for Advanced Computing in Europe (PRACE)

- HPCU actively seeks participation from all sectors of the HPC community to:
  - assess the learning and workforce development needs and requirements of the community,
  - catalog, disseminate and promote peer-reviewed and persistent HPC resources,
  - develop new content to fill the gaps to address community needs,
  - broaden access by a larger and more diverse community via a variety of delivery methods,
  - and pursue other activities as needed to address community needs
Initiatives and Developments in EU

- LERU (League of European Research Universities)
  - LERU Roadmap for Research Data
    - Prepared by the LERU Research Data Working Group
    - Valuable contribution from LIBER, UKOLN

- EGI (European Grid Initiative) Education and Training initiative

- EUDAT Training program on Research Data and tools

- EDISON Initiative (UvA, EGI, others)
  - Education for Data Intensive Science to Open New science frontiers

- Initiatives from industry and commercial companies to support Data Science and Big Data education
  - E.g. Engineering Group (HQ Italy) & Politecnico Turino, KPMG (NL) & UvA, Elsevier/LexisNexis (& UvA)
EGI Partners to cooperate on Edu@Skills

- National Centre for Scientific Research (CNRS, France)
- INFN (Italy) and University of Catania
- ENGINEERING (Italy) and Politecnico of Torino
- Alliance Permanent Archives (APA) and APARSEN Project
  - FTK (Formal Education and Curricula)
  - GLOBIT (Online Continuous Professional Education Portal)
  - DANS (Education and Training Resources)
  - INMARK (Spreading Excellence)
- University of Amsterdam (UvA)
  - Data Science Research Center
  - Academic Medical Center (AMC)
Programme Structure

The first two semesters (September-May) are spent studying taught courses in Data Science. At the same time, research skills are developed as a preliminary for work on an MSc project. Exams take place at the end of each semester.

In the third semester (May-August), students undertake a specialist project and write it up as a dissertation. It enables development and consolidation of skills introduced in the taught courses, applying them to a challenging practical problem in the subject area.

The project is carried out under the supervision of an academic who is an expert in the field. In some cases, the project can be carried out in collaboration with an outside industrial or academic organisation.

The table shows the essential and optional courses in the first 2 semesters. Full-time students must study 4 courses each semester.

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<tr>
<td><strong>Essential:</strong></td>
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<tr>
<td>F21CN Computer Network Security</td>
<td>F21BD Big Data Management</td>
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<td>F21DL Data Mining and Machine Learning</td>
<td>F21DP Distributed and Parallel Technologies</td>
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<td>F21DV Data Visualization and Analytics</td>
<td>F21RP Research Methods &amp; Project Planning</td>
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<tr>
<td><strong>Optional:</strong></td>
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<tr>
<td>F21MA 3D Modelling and Animation</td>
<td>F21AD Advanced Interaction Design</td>
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<td>F21BC Biologically Inspired Computation</td>
<td>F21AS Advanced Software Engineering</td>
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<td>F21SF Software Engineering Foundations</td>
<td>F21VR Virtual and Augmented Realities</td>
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<td>Seminar 8: Integrating Big Data applications into enterprise IT infrastructure, data regulation compliance</td>
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Seminar 1: Introduction. Big Data technology domain definition, Big Data Architecture Framework  
• **Topics:** Big Data and Data Intensive technologies definition; Big Data properties: Volume, Velocity, Variety, Variability, Value, And Veracity. Big Data ecosystem, data origin, data target; raw data and actionable data.

Seminar 2: Big Data use cases from Science, industry and business  
• **Topics:** Big data use cases analysis from science and industry: LHC in HEP, LOFAR/SKA in astronomy, genomic research, Internet or web: target advertisement, recommender system (e.g. Netflix), Web Search, fraud detection

Seminar 3: Architecture Framework for Big Data Ecosystem, Big Data Infrastructure components  
• **Topics:** Big Data Analytics Infrastructure and technology platforms, Enterprise Data Warehouses, MapReduce and Hadoop, new file systems and database architectures, NoSQL.

Seminar 4: Big Data analytic techniques, introduction to RapidMiner  
• **Topics:** Introduction to analytics and different analytical techniques. What are Analytics/Data Mining/Machine Learning? Introduction to the RapidMiner toolkit. The use of simple pre-processing and Statistical techniques for modeling data will be described and implemented using RapidMiner.

Seminar 5: Understanding the processes behind Big Data  
• **Topics:** Introduction to Rule Extraction Algorithms and Cluster Analysis. Evaluating data from text streams. Decision tree induction and Cluster Analysis techniques, use for enhancing business processes.

Seminar 6: Classification and forecasting techniques  
• **Topics:** Machine Learning techniques, Neural Networks and Support Vector Machines, techniques used to analyze the performance of our analytic processes. Measurement techniques such as Receiver Operating Curves and Gains Charts.

Seminar 7: Big Data Security, Protection, and Privacy  
• **Topics:** Big Data security and data protection; data centric security models. Big Data privacy issues, differential privacy and data re-identification.

Seminar 8: Integrating Big Data applications into enterprise IT infrastructure, data regulation compliance  
• **Topics:** Enterprise business processes and data management issues; analysis, evaluation and optimisation; enterprise data applications engineering. Data protection and corresponding standards, regulation and legislation; data provenance.
Data are becoming infrastructure themselves (Report “Riding the Wave”)

- This requires large infrastructure resources to collect, store, process and archive heterogeneous multi-faceted and linked data.
- Data centric/data driven infrastructure has to support different types of data, including text data, structured and unstructured data, relational and vector data, linked data.
- Data appear in various contexts: large number strings from experiments or sensors, in software code, music, films, publications, digital art, web pages, social media, public and business statistics, and also orphan data.
- We need data scientists with the knowledge and skill to work with existing and future data intensive infrastructure and tools.
Data scientists have to get familiar with the data universe and the peculiarities of this landscape. They will work in research, specific scientific data domains, and in the private sector.
EDISON: Anticipated curriculum development

- Create a cooperative community with universities that offer bachelor and master programs in Data Science, Big Data and Data Archives.
- Consider the educational focus with a vision on the developing data universe.
- Test and adapt educational programmes.
- Address implementation strategies with respect to required expertise, methods, research training, management and financial implications.
- Promote awareness and recognition (inform the market sector; secure certification of new educational tracks).
EDISON: Next steps

• Formal establishment of the RDA Interest Group on Education and Skills Development for Research Data

• Workshop – September 2014
  – Adjacent to the next RDA4 meeting in Amsterdam

• Information exchange: Website and billboard
There will be a shortage of talent necessary for organizations to take advantage of Big Data.

- By 2018, the United States alone could face a shortage of 140,000 to 190,000 people with deep analytical skills as well as
- 1.5 million managers and analysts with the know-how to use the analysis of big data to make effective decisions

SOURCE: US Bureau of Labor Statistics; US Census; Dun & Bradstreet; company interviews; McKinsey analysis
Analysing the Analysers. O’Reilly Strata Survey – Harris, Murphy & Vaisman, 2013
- Based on how data scientists think about themselves and their work
- Identified four Data Scientist clusters

Data Developer
- Developer
- Engineer

Data Researcher
- Researcher
- Scientist
- Statistician

Data Creative
- Jack of All Trades
- Artist
- Hacker

Data Businessperson
- Leader
- Businessperson
- Entrepreneur
Skills and Self-ID Top Factors

Business
ML/BigData
Math/OR
Programming
Statistics

ML – Machine Learning
OR – Operations Research
Slide from the presentation  
Demystifying Data Science  
(by Natasha Balac, SDSC)
Key to a Great Data Scientist

Technical skills (Coding, Statistics, Math)
  + Commitment + Creativity
  + Intuition
  + Presentation Skills
  + Business Savvy

= Great Data Scientist!

• How Long Does It Take For a Beginner to Become a Good Data Scientist?
  – 3-5 years according to KDnuggets survey [278 votes total]
Questions and Discussion
Additional Information

• Example Cloud Computing course development
Common Body of Knowledge (CBK) in Cloud Computing

CBK refers to several domains or operational categories into which Cloud Computing theory and practices breaks down

- Still in development but already piloted by some companies, including industry certification program (e.g. IBM, AWS?)

CBK Cloud Computing elements

1. *Cloud Computing Architectures, service and deployment models*
2. *Cloud Computing platforms, software/middleware and API’s*
3. *Cloud Services Engineering, Cloud aware Services Design*
4. Virtualisation technologies (Compute, Storage, Network)
5. Computer Networks, Software Defined Networks (SDN)
6. Service Computing, Web Services and Service Oriented Architecture (SOA)
7. Computing models: Grid, Distributed, Cluster Computing
8. Security Architecture and Models, Operational Security
9. IT Service Management, Business Continuity Planning (BCP)
10. Business and Operational Models, Compliance, Assurance, Certification
CKB-Cloud Components Landscape

Cloud Computing Fundamentals

- Cloud Architectures, Service Models
- Cloud Platforms, API

Cloud Services Engineering & Design
- Design
- Engineering

- Virtualisation
- Networking
- Web Services, SOA
- Security, ID Management

- Computing Models: Grid, Distributed, Cluster
- IT Systems Management

Cloud Computing Common Body of Knowledge (Full)

- Business Operational Models, Compliance, Assurance
Multilayer Cloud Services Model (CSM) – Taxonomy of Existing Cloud Architecture Models

<table>
<thead>
<tr>
<th>CSM layers</th>
<th>(C6) User/Customer side Functions</th>
<th>(C5) Services Access/Delivery</th>
<th>(C4) Cloud Services (Infrastructure, Platform, Applications)</th>
<th>(C3) Virtual Resources Composition and Orchestration</th>
<th>(C2) Virtualisation Layer</th>
<th>(C1) Hardware platform and dedicated network infrastructure</th>
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### Layer C6
- User/Customer side Functions

### Layer C5
- Services Access/Delivery

### Layer C4
- Cloud Services (Infrastructure, Platform, Applications)

### Layer C3
- Virtual Resources Composition and Orchestration

### Layer C2
- Virtualisation Layer

### Layer C1
- Physical Hardware Platform and Network

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### CSM layers Diagram

- **Layer C6**: User/Customer side Functions
- **Layer C5**: Services Access/Delivery
- **Layer C4**: Cloud Services (Infrastructure, Platform, Applications)
- **Layer C3**: Virtual Resources Composition and Orchestration
- **Layer C2**: Virtualisation Layer
- **Layer C1**: Physical Hardware Platform and Network

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### Other Information

- Cloud Management Platforms: OpenNebula, OpenStack, Other CMS
- Virtualisation Platforms: KVM, XEN, VMware, Virtualis
- Control/Management Links: ↔
- Data Links: ↔

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Relations Course Components and CSM

Layer C6
User/Customer side Functions

Layer C5
Services Access/Delivery

Layer C4
Cloud Services (Infrastructure, Platforms, Applications, Software)

Layer C3
Virtual Resources Composition and Control (Orchestration)

Layer C2
Virtualisation

Layer C1
Physical Hardware Platform and Network

Customer Enterprise/Campus Infrastructure/Facility
Hybrid Clouds, Integrated Infrastructure

User Applications

Cloud Service Provider Datacenters and Infrastructure

Cloud Services Platform

Cloud/Intercloud Services Integration, Enterprise IT infrastructure migration

Cloud Service Design, Operational procedures

Cross-layer Services (Planes)
Operations Support System
Security
Management

Cloud Services API and Tools

User Applications

Datacenters and Infrastructure

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Professional Education in Cloud Computing - Principles

• Provide knowledge both in **Cloud Computing** as a new technology and **background technologies**

• Empower the future professionals with ability to **develop new knowledge** and build stronger expertise, prepare basis for new **emerging technologies** such as **Big Data**

• **Bloom’s Taxonomy** as a basis for defining learning targets and modules outcome
  • Provides a basis for knowledge testing and certification

• **Andragogy vs Pedagogy** as instructional methodology for professional education and training
  • Course format: On-campus education and training, online courses, self-study
Bloom’s Taxonomy – Cognitive Activities

**Knowledge**
Exhibit memory of previously learned materials by recalling facts, terms, basic concepts and answers
- Knowledge of specifics - terminology, specific facts
- Knowledge of ways and means of dealing with specifics - conventions, trends and sequences, classifications and categories, criteria, methodology
- Knowledge of the universals and abstractions in a field - principles and generalizations, theories and structures
- **Questions like:** What are the main benefits of outsourcing company’s IT services to cloud?

**Comprehension**
Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, describing, and stating the main ideas
- Translation, Interpretation, Extrapolation
- **Questions like:** Compare the business and operational models of private clouds and hybrid clouds.

**Application**
Using new knowledge. Solve problems in new situations by applying acquired knowledge, facts, techniques and rules in a different way
- **Questions like:** Which cloud service model is best suited for medium size software development company, and why?

**Analysis**
Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations
- Analysis of elements, relationships, organizational principles
- **Questions like:** What cloud services are needed to support typical business processes of a web trading company? Give suggestions how these services can be implemented with PaaS or IaaS clouds. Provide references to support your statements.

**Synthesis**
Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions
- Production of a unique communication, a plan, or proposed set of operations, derivation of a set of abstract relations
- **Questions like:** Describe the main steps and tasks for migrating IT services of an example company to clouds? What services and data can be moved to clouds and which will remain at the enterprise premises.

**Evaluation**
Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria
- Judgments in terms of internal evidence or external criteria
- **Questions like:** Do you think that cloudification of the enterprise infrastructure creates benefits for enterprises, short term and long term?
Mapping Bloom’s Taxonomy from Cognitive Domain to Professional Activity Domain

- Perform standard tasks, use API and Guidelines
- Create own complex applications using standard API (simple engineering)
- Integrate different systems/components, e.g. Cloud provider and enterprise (complex engineering)
- Extend existing services, design new services
- Develop new architecture and models, platforms and infrastructures
Mapping Course Components, Cloud Professional Activity and Bloom’s Taxonomy

Taxonomy
Cognitive Domain [3]

Knowledge

Comprehension

Application

Analysis

Synthesis

Evaluation

Cloud Service Design, Operational procedures

Cloud/Intercloud Services Integration, Enterprise IT infrastructure migration

Cloud Services Platform

Cloud Service Provider

Datacenters and Infrastructure

Customer Enterprise/Campus Infrastructure/Facility

Hybrid Clouds, Integrated Infrastructure

User Applications

Cloud Services API and Tools

Perform standard tasks, use standard API and Guidelines

Create own complex applications using standard API (simple engineering)

Integrate different systems/components, e.g. provider and enterprise infrastructure

Extend existing services, design new services

Develop new architecture and models, platforms and infrastructures

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Pedagogy vs Andragogy

Pedagogy (child-leading) and Andragogy (man-leading)
• On-campus and on-line education
• Developed by American educator Malcolm Knowles, stated with six assumptions related to motivation of adult learning:
  – Adults need to know the reason for learning something (Need to Know)
  – Experience (including error) provides the basis for learning activities (Foundation)
  – Adults need to be responsible for their decisions on education; involvement in the planning and evaluation of their instruction (Self-concept)
  – Adults are most interested in learning subjects having immediate relevance to their work and/or personal lives (Readiness).
  – Adult learning is problem-centered rather than content-oriented (Orientation)
  – Adults respond better to internal versus external motivators (Motivation)
Applying Andragogy to Self-Education and Online Training - Problems

• Andragogy concept is widely used in on-line education but
  – Based on active discussion activities guided/moderated by instructor/moderator
  – Combined with the Bloom’s taxonomy

• Self-education (guided) and online training specifics
  – Course consistency in sense of style, presentation/graphics, etc
  – Requires the course workflow to be maximum automated
    • Especially if coupled with certification or pre-certification
  – Less time to be devoted by trainee
    • Estimated 1 hour per lesson, maximum 3 lessons per topic
  – Knowledge control questionnaires at the end of lessons or topics