Education for Data Intensive Science and the EDISON project:

Role of skills management and capacity building for sustainable EOSC development

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EDISON – Education for Data Intensive Science to Open New science frontiers

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Outline

• EOSC HLEG Report and Core Data skills gap
  – Bridging cultures between Science and e-Infrastructure
  – Need for conceptual approach to address EOSC challenge of core data experts/skills gap

• EDISON Data Science Framework (EDSF)
  – From Data Science Competences to Body of Knowledge and Model Curriculum
  – New organisational role and Data Science Professional profiles

• Wide spectrum of activities and initiatives worldwide to establish Data (Science) professions family
  – BHEF, DARE/APEC, IEEE/ACM
Recent European Commission Initiatives 2016


- The need for new multidisciplinary and digital skills in particular Data Scientist
  - Expected rapidly growing demand will lead to more than 800,000 unfilled vacancies by 2020


- European Open Science Cloud (EOSC) and European digital research and data infrastructure
  - To offer 1.7 million European researchers and 70 million professionals in science and technology open and seamless services for storage, management, analysis and re-use of research data

- Address growing demand and shortage of data-related skills


- Addresses the need for digital and complementary skills, ensure young talents flow into data driven research and industry

- Launched Digital Skills and Jobs Coalition (1st December 2016, Brussels) to develop comprehensive national digital skills strategies by mid-2017

- Recommendation: Allocate 5% grant funding for Data management and preservation
- Estimation: More than 80,000 data stewards to serve 1.7 mln scientists in Europe (1 per every 20 scientists)
  - Number of data workers 6.1 mln (2014) - increase 5.7% from 2013
  - Average number of data workers per company 9.5 - increase 4.4%
  - Gap between demand and supply 509,000 (2014) or 7.5%
- Core data experts need to be trained and their career perspective improved
Core Data Experts is a new class of colleagues with core scientific professional competencies and the communication skills to fill the gap between the two cultures.

- Core data experts are neither computer savvy research scientists nor are they hard-core data or computer scientists or software engineers.
- They should be technical data experts, though proficient enough in the content domain where they work routinely from the very beginning (experimental design, proposal writing) until the very end of the data discovery cycle.
- Converge two communities:
  - Scientists need to be educated to the point where they hire, support and respect Core Data Experts
  - Data Scientists (Core Data Experts) need to bring the value to scientific research and organisations

Implementation of the EOSC needs to include instruments to help train, retain and recognise this expertise,
- In order to support the 1.7 million scientists and over 70 million people working in innovation.
• **I2.1:** Set initial guiding principles to kick-start the initiative as quickly as possible. -> **Bridge two cultures/communities**
  – A first cohort of core data experts should be trained to translate the needs for data driven science into technical specifications to be discussed with **hard-core data scientists and engineers.**
  – This new class of core data experts will also help translate back to the **hard-core scientists** the technical opportunities and limitations

• **I3:** **Fund a concerted effort to develop core data expertise in Europe.**
  – Substantial training initiative in Europe to locate, create, maintain and sustain the required core data expertise.
  – **By 2022, to train (hundreds of thousands of) certified core data experts** with a demonstrable effect on ESFRI/e-INFRA activities and prospects for long-term sustainability of this critical human resource
    • Consolidate and further develop assisting material and tools for Data Management Plans and Data Stewardship plans (including long-term preservation in FAIR status)

• **I7:** **Provide a clear operational timeline to deal with the early preparatory phase of the EOSC.**
  – Define training needs for the necessary data expertise and draw models for the necessary training infrastructure
Approach

- Task is not for one community or one project
  - Need collaboration between different stakeholders and communities: academia, research, industry, public sector

- Task is not for science or RI only in isolation from industry and academia

- Needs strong conceptual approach
  - Use science to solve the problems of science

- Standardisation is an important factor of sustainability and development
**EDISON Data Science Framework (EDSF)**
- Compliant with EU standards on competences and professional occupations e-CFv3.0, ESCO
- Customisable courses design for targeted education and training

**Skills development and career management for Core Data Experts and related data handling professions**

**Capacity building and Data Science team design**

**Academic programmes and professional training courses (self) assessment and design**

**EU network of Champion universities pioneering Data Science academic programmes**

**Engagement in relevant RDA activities and groups**

**Cooperation with International professional organisations IEEE, ACM, BHEF, APEC (AP Economic Cooperation )**
EDISON Data Science Framework (EDSF) Release 1 (October 2016)

- **Foundation & Concepts**
  - CF-DS – Data Science Competence Framework
  - DS-BoK – Data Science Body of Knowledge
  - MC-DS – Data Science Model Curriculum
  - DSP – Data Science Professional profiles
  - Data Science Taxonomies and Scientific Disciplines Classification
  - EOEE - EDISON Online Education Environment

- **Services**
  - EDISON Online Educational Environment
  - Edu&Train Marketpltz and Directory

- **Biz Model**
  - Roadmap & Sustainability
    - Community Portal (CP)
    - Professional certification
    - Data Science career & prof development

**EDISON Framework components**

- CF-DS – Data Science Competence Framework
- DS-BoK – Data Science Body of Knowledge
- MC-DS – Data Science Model Curriculum
- DSP – Data Science Professional profiles
- Data Science Taxonomies and Scientific Disciplines Classification
- EOEE - EDISON Online Education Environment
Data Science Professions Family

**Managers:** Chief Data Officer (CDO), Data Science (group/dept) manager, Data Science infrastructure manager, Research Infrastructure manager

**Professionals:** Data Scientist, Data Science Researcher, Data Science Architect, Data Science (applications) programmer/engineer, Data Analyst, Business Analyst, etc.

**Professional (database):** Large scale (cloud) database designers and administrators, scientific database designers and administrators

**Professional (data handling/management):** Data Stewards, Digital Data Curator, Digital Librarians, Data Archivists

**Technicians and associate professionals:** Big Data facilities operators, scientific database/infrastructure operators

**Support workers and data handling clerks:** User support workers, data entry clerks, data entry field workers

Icons used: Credit to [ref] https://www.datacamp.com/community/tutorials/data-science-industry-infographic
DSP Profiles mapping to ESCO Taxonomy
High Level Groups

DSP Profiles mapping to corresponding CF-DS Competence Groups
- Relevance level from 5 – maximum to 1 – minimum
Data Scientist definition

Based on the definitions by NIST Big Data WG (NIST SP1500 - 2015)

- **Data Scientist** is a practitioner who has sufficient knowledge in the overlapping regimes of expertise in business needs, domain knowledge, analytical skills, and programming and systems engineering expertise to manage the end-to-end scientific method process through each stage in the **big data lifecycle**
  - … Till the delivery of an **expected scientific and business value** to science or industry

- **Other definitions to admit such features as**
  - Ability to solve variety of business problems
  - Optimize performance and suggest new services for the organisation
  - Develop a special mindset and be statistically minded, **understand raw data** and “recognize data as a first class product”

- **Data science** is the empirical synthesis of actionable knowledge and technologies required to handle data from raw data through the complete data lifecycle process.
- **Big Data** is the technology to build system and infrastructures to process large volume of structurally complex data in a time effective way
Identified Data Science Competence Groups

- **Core Data Science competences/skills groups**
  - **Data Science Analytics** (including Statistical Analysis, Machine Learning, Business Analytics)
  - **Data Science Engineering** (including Software and Applications Engineering, Data Warehousing, Big Data Infrastructure and Tools)
  - **Domain Knowledge and Expertise** (Subject/Scientific domain related)

- **EDISON identified 5 core competence groups demanded by organisations**
  - **Data Management, Curation, Preservation**
  - **Scientific or Research Methods and vs Business Processes/Operations**

- **Other skills commonly recognized aka “soft skills” or “21st Century Skills”**
  - Inter-personal skills and team work, cooperativeness

- **Important aspect of integrating Data Scientist (team) into organisation structure**
  - General Data Science (and Data) **literacy** for all involved roles and management
  - **Role of Data Scientist: Provide a kind of literacy advice and guidance to organisation**
Data Science Competence Groups - Research

Data Science Competence includes 5 areas/groups
- Data Analytics
- Data Science Engineering
- Domain Expertise
- Data Management
- Scientific Methods (or Business Process Management)

Scientific Methods
- Design Experiment
- Collect Data
- Analyse Data
- Identify Patterns
- Hypothesise Explanation
- Test Hypothesis

Business Operations
- Operations Strategy
- Plan
- Design & Deploy
- Monitor & Control
- Improve & Re-design
Data Science Competence includes 5 areas/groups

- Data Analytics
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- Domain Expertise
- Data Management
- Scientific Methods (or Business Process Management)

Scientific Methods

- Design Experiment
- Collect Data
- Analyse Data
- Identify Patterns
- Hypothesise Explanation
- Test Hypothesis

Business Process Operations/Stages

- Design
- Model/Plan
- Deploy & Execute
- Monitor & Control
- Optimise & Re-design
## Identified Data Science Competence Groups

<table>
<thead>
<tr>
<th>Data Science Analytics (DSDA)</th>
<th>Data Management (DSDM)</th>
<th>Data Science Engineering (DSENG)</th>
<th>Research/Scientific Methods (DSRM)</th>
<th>Data Science Domain Knowledge, e.g. Business Processes (DSDK/DSBPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Use appropriate statistical techniques and predictive analytics on available data to deliver insights and discover new relations</td>
<td>Develop and implement data management strategy for data collection, storage, preservation, and availability for further processing.</td>
<td>Use engineering principles to research, design, develop and implement new instruments and applications for data collection, analysis and management</td>
<td>Create new understandings and capabilities by using the scientific method (hypothesis, test/artefact, evaluation) or similar engineering methods to discover new approaches to create new knowledge and achieve research or organisational goals</td>
<td>Use domain knowledge (scientific or business) to develop relevant data analytics applications, and adopt general Data Science methods to domain specific data types and presentations, data and process models, organisational roles and relations</td>
</tr>
<tr>
<td>1 DSDA01 Use predictive analytics to analyse big data and discover new relations</td>
<td>DSDM01 Develop and implement data strategy, in particular, Data Management Plan (DMP)</td>
<td>DSENG01 Use engineering principles to design, prototype data analytics applications, or develop instruments, systems</td>
<td>DSRM01 Create new understandings and capabilities by using scientific/research methods or similar domain related development methods</td>
<td>DSBPM01 Understand business and provide insight, translate unstructured business problems into an abstract mathematical framework</td>
</tr>
<tr>
<td>2 DSDA02 Use statistical techniques to deliver insights</td>
<td>DSDM02 Develop data models including metadata</td>
<td>DSENG02 Develop and apply computational solutions</td>
<td>DSRM02 Direct systematic study toward a fuller knowledge or understanding of the observable facts</td>
<td>DSBPM02 Participate strategically and tactically in financial decisions</td>
</tr>
<tr>
<td>3 DSDA03 Develop specialized …</td>
<td>DSDM03 Collect integrate data</td>
<td>DSENG03 Develops specialized tools</td>
<td>DSRM03 Undertakes creative work</td>
<td>DSBPM03 Provides support services to other</td>
</tr>
<tr>
<td>4 DSDA04 Analyze complex data</td>
<td>DSDM04 Maintain repository</td>
<td>DSENG04 Design, build, operate</td>
<td>DSRM04 Translate strategies into actions</td>
<td>DSBPM04 Analyse data for marketing</td>
</tr>
<tr>
<td>5 DSDA05 Use different analytics</td>
<td>DSDM05 Visualise complex data</td>
<td>DSENG05 Secure and reliable data</td>
<td>DSRM05 Contribute to organizational goals</td>
<td>DSBPM05 Analyse optimise customer relatio</td>
</tr>
</tbody>
</table>
Identified Data Science Skills/Experience Groups

- **Group 1: Skills/experience related to competences**
  - Data Analytics and Machine Learning
  - Data Management/Curation (including both general data management and scientific data management)
  - Data Science Engineering (hardware and software) skills
  - Scientific/Research Methods or Business Process Management
  - Application/subject domain related (research or business)
  - Mathematics and Statistics

- **Group 2: Big Data (Data Science) tools and platforms**
  - Big Data Analytics platforms
  - Mathematics & Statistics applications & tools
  - Databases (SQL and NoSQL)
  - Data Management and Curation platform
  - Data and applications visualisation
  - Cloud based platforms and tools

- **Group 3: Programming and programming languages and IDE**
  - General and specialized development platforms for data analysis and statistics

- **Group 4: Soft skills or Social Intelligence**
  - Personal, inter-personal communication, team work, professional network
Practical Application of the CF-DS

- Basis for the definition of the Data Science Body of Knowledge (DS-BoK) and Data Science Model Curriculum (MC-DS)
  - CF-DS => Learning Outcomes (MC-DS) => Knowledge Areas (DS-BoK)
  - CF-DS => Data Science taxonomy of scientific subjects and vocabulary

- Data Science professional profiles definition
  - Extend existing EU standards and occupations taxonomies: e-CFv3.0, ESCO, others

- Professional competence benchmarking
  - For customizable training and career development
  - Including CV or organisational profiles matching

- Professional certification
  - In combination with DS-BoK professional competences benchmarking

- Vacancy construction tool for job advertisement (for HR)
  - Using controlled vocabulary and Data Science Taxonomy
Education and Training

• Foundation and methodological base
  – Data Science Body of Knowledge (DS-BoK)
    • Taxonomy and classification of Data Science related scientific subjects
  – Data Science Model Curriculum (MC-DS)
    • Set Learning Units mapped to CF-DS Learning and DS-BoK Knowledge Areas/Units
  – Instructional methodologies and teaching models

• Platforms and environment
  – Virtual labs, datasets, developments platforms
  – Online education environment and courses management

• Services
  – Individual benchmarking and profiling tools (competence assessment)
  – Knowledge evaluation tools
  – Certifications and training for self-made Data Scientists practitioners
  – Education and training marketplace: Courses catalog and repository
DS-BoK Knowledge Area Groups (KAG)

- **KAG1-DSA**: Data Analytics group including Machine Learning, statistical methods, and Business Analytics
- **KAG2-DSE**: Data Science Engineering group including Software and infrastructure engineering
- **KAG3-DSDM**: *Data Management group including data curation, preservation and data infrastructure*
- **KAG4-DSRM**: *Scientific/Research Methods group*
- **KAG5-DSBP**: Business process management group

- Data Science domain knowledge to be defined by related expert groups
Data Science Model Curriculum includes

- **Learning Outcomes (LO) definition based on CF-DS**
  - LOs are defined for CF-DS competence groups and for all enumerated competences

- **LOs mapping to Learning Units (LU)**
  - LUs are based on CCS(2012) and universities best practices
  - Data Science university programmes and courses inventory (interactive)
    - [http://edison-project.eu/university-programs-list](http://edison-project.eu/university-programs-list)

- **LU/course relevance**: Mandatory Tier 1, Tier 2, Elective, Prerequisite

- **Learning methods and learning models** (in progress)
Example MC-DS Mapping Learning Units to DS-BoK and CCS (2012)

<table>
<thead>
<tr>
<th>KAG/ LU#</th>
<th>Learning Unit (course name)</th>
<th>Type/relevance</th>
<th>Map to DS-BoK, CCS2012 and known BoKs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tier 1 Tier 2</td>
<td>Elective Pre requisite</td>
</tr>
<tr>
<td>Software requirements and design</td>
<td></td>
<td></td>
<td>DS-BoK and other BoKs</td>
</tr>
<tr>
<td>Information theory</td>
<td>Mathematical analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematical analysis</td>
<td>Extensibility point for adding new courses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial Intelligence</td>
<td>Natural Language Processing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* KAG/ LU# denotes Knowledge Area Group and Learning Unit number.

Mapping suggested to ACM CCS2012, DS-BoK and other related BoKs

- Data mining and knowledge discovery: Data type registries, PID, metadata
- Text analysis, Data: Research data infrastructure, Open Science, Open Data, Open Access, ORCID
- Machine Learning algorithms: Extensibility point for adding new courses
- Classification methods: Research methodology, research cycle, Modelling and experiment planning

Extended with the general Data Management Knowledge Areas and related academic subjects.

Suggested KAs to develop DSRM related competences:
- Research methodology, research cycle (e.g. 4 step model: Hypothesis – Research Methods – Artefact –
Outcome Based Educations and Training Model

From Competences and DSP Profiles to Learning Outcomes (LO) and to Knowledge Units (KU) and Learning Units (LU)

- EDSF allow for customized educational courses and training modules design
Individual Competences Benchmarking

Individual Education/Training Path based on Competence benchmarking

- Red polygon indicates the chosen professional profile: Data Scientist (general)
- Green polygon indicates the candidate or practitioner competences/skills profile
- Insufficient competences (gaps) are highlighted in red
  - DSDA01 – DSDA06 Data Science Analytics
  - DSRM01 – DSRM05 Data Science Research Methods
- Can be used for team skills match marking and organisational skills management

[ref] For DSP Profiles definition and for enumerated competences refer to EDSF documents CF-DS and DSP Profiles.
Building a Data Science Team

Data Science Group
Manager, Data Science Architect

Data Source
(Experiment, Data Driven Application)

Data Collection

Data Ingest

Data Analysis

Results, Actionable Data

Data Visualisation, Reporting, Storage

Data Steward

Data Scientist

Data Analyst/Business Analyst

Data Science Applications Developer

Data Engineer, Database Developer

Data Steward

Data Science Researcher

Researcher (Scientific domain)

Data Facilities Operator

Data Entry/Support

Data Scientist

Data Scientist

Business Analyst

Data Steward

Business Analyst

Data Steward
Data Science or Data Management Group/Department

- (Managing) Data Science Architect (1)
- Data Scientist (1), Data Analyst (1)
- Data Science Application programmer (2)
- Data Infrastructure/facilities administrator/operator: storage, cloud, computing (1)
- Data stewards, curators, archivists (3-5)

Estimated: Group of 10-12 data specialists for research institution of 200-300 research staff.

>> Reporting to CDO/CTO/CEO
  • Providing cross-organizational services
DM-BoK version 2 “Guide for performing data management” – 11 Knowledge Areas

(1) Data Governance
(2) Data Architecture
(3) Data Modelling and Design
(4) Data Storage and Operations

(5) Data Security
(6) Data Integration and Interoperability

(7) Documents and Content
(8) Reference and Master Data
(9) Data Warehousing and Business Intelligence

(10) Metadata
(11) Data Quality

Other Knowledge Areas motivated by RDA, European Open Data initiatives, European Open Data Cloud

(12) PID, metadata, data registries
(13) Data Management Plan
(14) Open Science, Open Data, Open Access, ORCID
(15) Responsible data use

• Highlighted in red: Considered (Research) Data Management literacy (minimum required knowledge)
Useful links

• EDISON project website [http://edison-project.eu/](http://edison-project.eu/)


• Survey Data Science Competences: Invitation to participate [https://www.surveymonkey.com/r/EDISON_project_-_Defining_Data_science_profession](https://www.surveymonkey.com/r/EDISON_project_-_Defining_Data_science_profession)
Data Scientist and Subject Domain Specialist

• **Subject domain components**
  – Model (and data types)
  – Methods
  – Processes
  – Domain specific data and presentation/visualization methods
  – Organisational roles and relations

• **Data Scientist is an assistant to Subject Domain Specialists**
  – Translate subject domain Model, Methods, Processes into abstract data driven form
  – Implement computational models in software, build required infrastructure and tools
  – Do (computational) analytic work and present it in a form understandable to subject domain
  – Discover new relations originated from data analysis and advice subject domain specialist
  – Present/visualise information in domain related actionable way
  – Interact and cooperate with different organizational roles to obtain data and deliver results and/or actionable data
Data Science and Subject Domains

Data Science domain components

- Data structures & databases/storage
- Visualisation

- Abstract data driven math&compute models
- Data Analytics methods
- Data and Applications Lifecycle Management

Cross-organisational assistive role

Domain specific components

- Domain specific data & presentation (visualization)

- Models (and data types)
- Methods
- Processes

Organisational roles

Data Scientist functions is to translate between two domains

Data Scientist role is to maintain the Data Value Chain (domain specific):
- Data Integration => Organisation/Process/Business Optimisation => Innovation