AECOO Education –

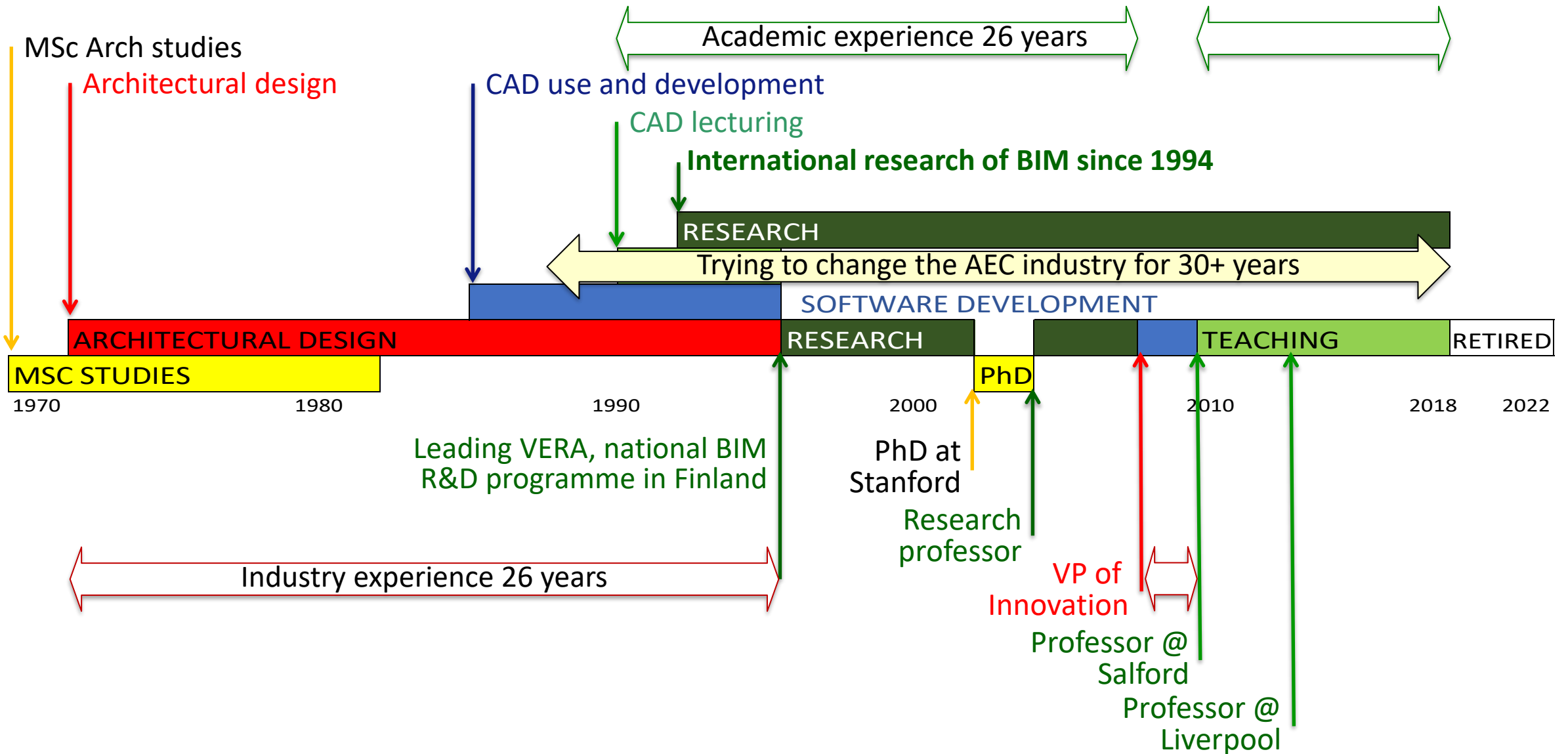## *Do we need a new teaching paradigm?*

Arto Kiviniemi

Honorary Research Senior Fellow &
Retired Professor of Digital Architectural Design
University of Liverpool

Arto Kiviniemi – career

- Extensive experience in architectural design 1972-1996
  - Architect Office Arto Sipinen 1973…91: 12 first prizes and several other prizes in architectural competitions, 25 completed projects
    - Cultural centres, concert halls, town halls, university buildings…
  - My own office Studio Kivi 1990...1996
    - Started as a design office, from 1991 focus increasingly in software development and ICT consultancy, and finally changing into a software vendor
  - Partner in Architect Office Arcadia 1991-1996

Architect Office Arto Sipinen 1973-91: Raisio Town Hall, Mikkeli Concert Hall, Tapiola Cultural Centre, Jyväskylä University Chemistry and Physics Laboratories, Helsinki Töölönlahti City Centre

Cultural Center of Tapiola 1981-1989

Architect Office Arto Sipinen

Global visibility since 1996…

- One of the globally leading experts of integrated BIM…
- 90 keynotes, 95 invited presentations, 26 journal papers, 49 refereed conference papers and several working papers, technical reports and chapters in books since 1996
- 7 memberships in editorial boards of journals, 60+ memberships in scientific committees of various international conferences and seminars since 2000
- Associate Professor in Ecole de technologies superior (ETS), Montreal, Canada, 2013-2016
- Several leading roles in buildingSMART International (former IAI):
  - Founding member and 1st Chair of BuildingSMART Nordic Chapter 1996-1998
  - International Council and Excel: Chair 1998-2000, Deputy Chair 2000-2002
  - International Technical Management Committee: Chair 2005-2007
  - Technical Advisory Group: Member since 2005
- FIATECH, member of several committees 2010-2013: Academic Committee, European Advisory Committee, Interoperability Committee, Conference Planning Committee
- Czech BIM Council, honorary member since 2011
- CIB IDDS (Integrated Design and Delivery Solutions), member of the Core Group since 2010
- ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers): member of the BIM Steering Committee since 2009
- Steering Committee of Salford Centre for Research and Innovation, Chair 2002-2009
- Scientific Committee in BuildingEnvelopes.org project at the Center of Design Informatics of Harvard University: Member 2001-2004
- Industrial Advisory Board and Technical Advisory Board of CIFE at Stanford University: Member 1999-2005

Tuba Kocaturk & Arto Kiviniemi (2019) Opportunities and challenges of BIM adoption in education. RIAS Quarterly, Autumn 2019, Issue 39

Short version
https://media.rias.org.uk/files/2019/10/21/731AC5A6-0B89-62B2-AE50-3AF93C64CBB2.pdf, pages 10-11
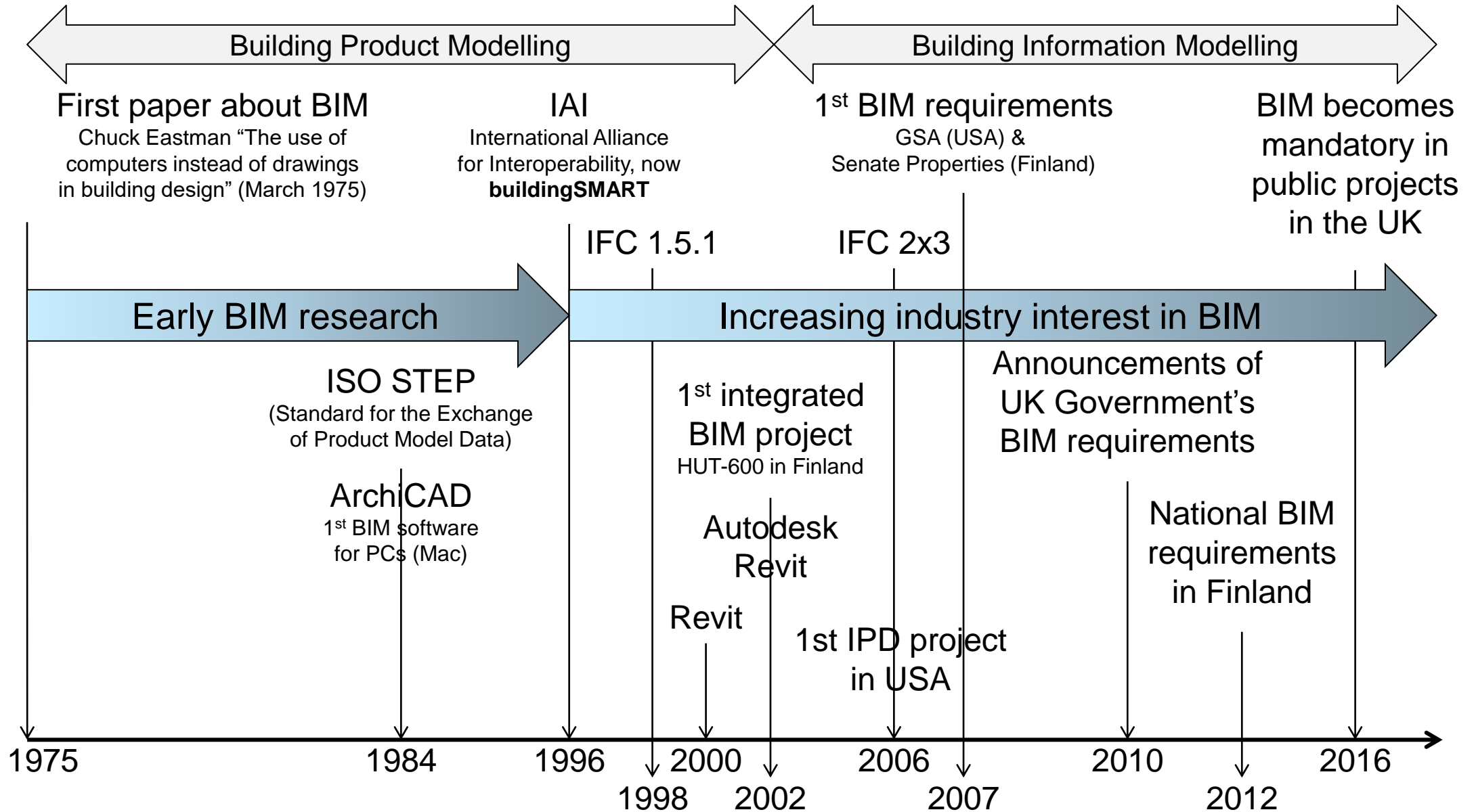
Full article at
https://media.rias.org.uk/files/2019/10/29/ABED1DE8-2F5E-888C-2254-D7F60D0395FB.pdf

The main question we must ask ourselves:
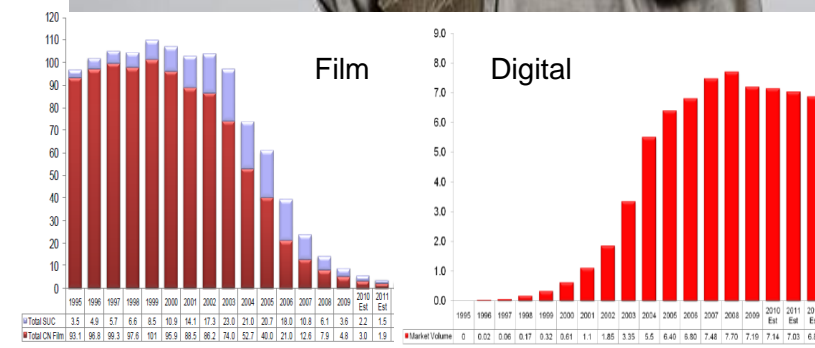
Are we educating for the past or for the future?

BIM is not a new issue...

Building Product Modelling → Building Information Modelling

First paper about BIM
Chuck Eastman "The use of computers instead of drawings in building design" (March 1975)

IAI
International Alliance for Interoperability, now **buildingSMART**

1st BIM requirements
GSA (USA) & Senate Properties (Finland)

BIM becomes mandatory in public projects in the UK

IFC 1.5.1

IFC 2x3

Early BIM research → Increasing industry interest in BIM

ISO STEP
(Standard for the Exchange of Product Model Data)

ArchiCAD
1st BIM software for PCs (Mac)

1st integrated BIM project
HUT-600 in Finland

Autodesk Revit

Revit

1st IPD project in USA

Announcements of UK Government's BIM requirements

National BIM requirements in Finland

1975   1984   1996   2000   2006   2010   2016
                        1998   2002   2007   2012

Construction industry has been slow to change

The Times They Are A-Changin'…

- In 1975 a Kodak scientist invented the digital camera. Kodak senior management were unimpressed because:
  - the camera was huge,
  - image quality was poor compared to film,
  - getting a print was complex requiring a PC and PC skills,
  - the film market was growing and so were Kodak sales and profits,
  - **if the technology could be improved, it would kill film – the Golden Goose.**

- The technology was buried until subsequent market emergence and Kodak's entry into digital in the late 1990's

- Business results:
  - In 1988 Kodak employed 145,300 people and made a profit of $1.17bn on $13.3bn revenue
  - In 2009 it employed 19,900 people and made a quarterly loss of $111m
  - In January 2012 Kodak filed for bankruptcy protection

Film

Digital

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 Est	2011 Est
Total SUC	3.5	4.9	5.7	6.6	8.5	10.9	14.1	17.3	23.0	21.0	20.7	18.0	10.8	6.1	3.6	2.2	1.5
Total CN Film	93.1	96.8	99.3	97.6	101	95.9	88.5	86.2	74.0	52.7	40.0	21.0	12.6	7.9	4.8	3.0	1.9

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 Est	2011 Est	2012 Est
Market Volume	0	0.02	0.06	0.17	0.32	0.61	1.1	1.85	3.35	5.5	6.40	6.80	7.48	7.70	7.19	7.14	7.03	6.88

The AEC professions are changing...

FUTURE CONSTRUCTION ROLES:
TEN MOST IN DEMAND JOBS TODAY DID NOT EXIST IN 2000

- ☑ BIM Engineer
- ☑ BIM Model Manager
- ☑ VDC Engineer
- ☑ BIM Director
- ☑ Design Strategist

- ☑ BIM Applications Manager
- ☑ Interoperability Programmer
- ☑ Social Media Manager
- ☑ Digital Making Technologist
- ☑ Information Manager

pre-2000
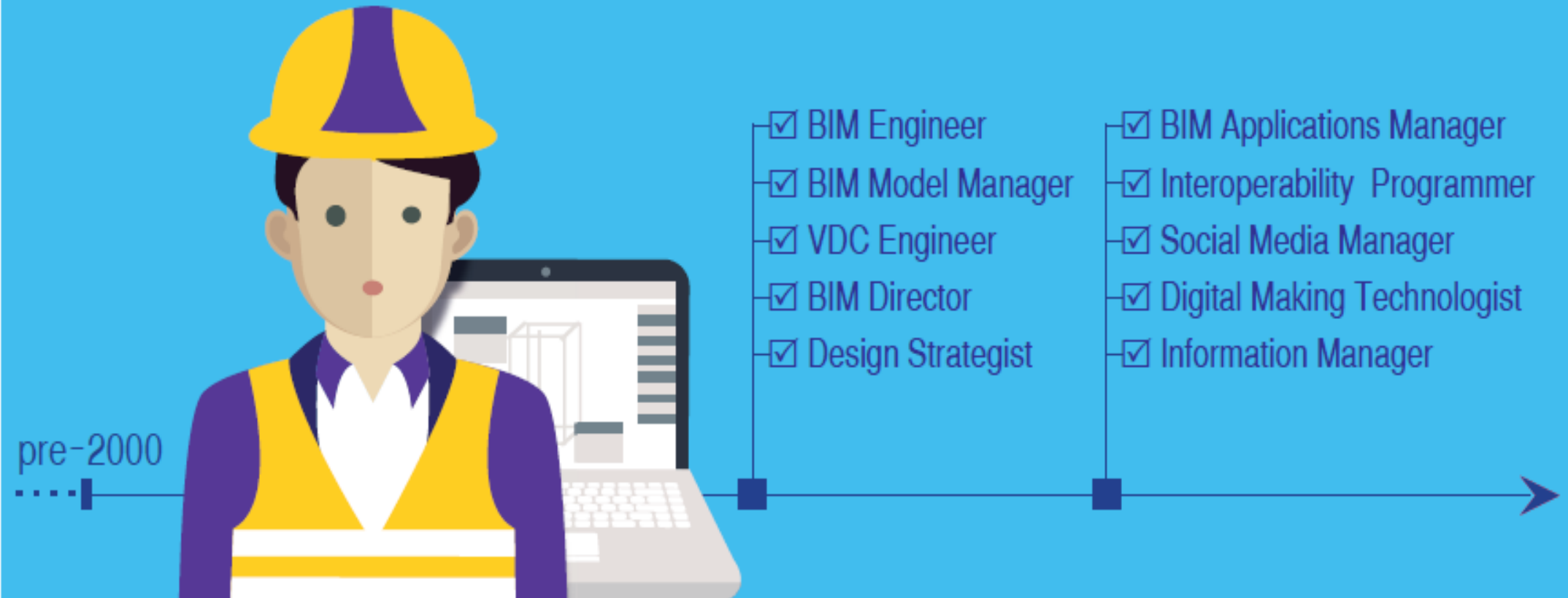
Courtesy David Philp 2016
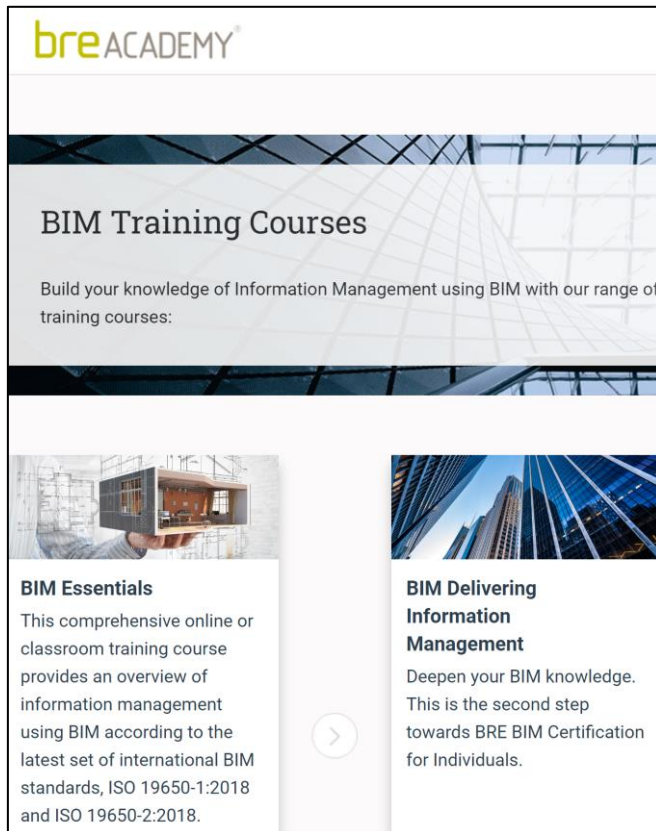
Current situation (in many universities)...

Where do you look for BIM education/training?

Who do you go to for BIM education/training?

Universities & colleges 10%

Others 90%

- 9.5% Universities
- 1.4% Colleges
- 35.1% Training providers
- 39.2% Software vendors
- 9.5% Commercial training centres
- 27.0% Institutions/Industry Bodies
- 45.9% In-house

Source: Internal Report for BRE BIM Prospects 2016
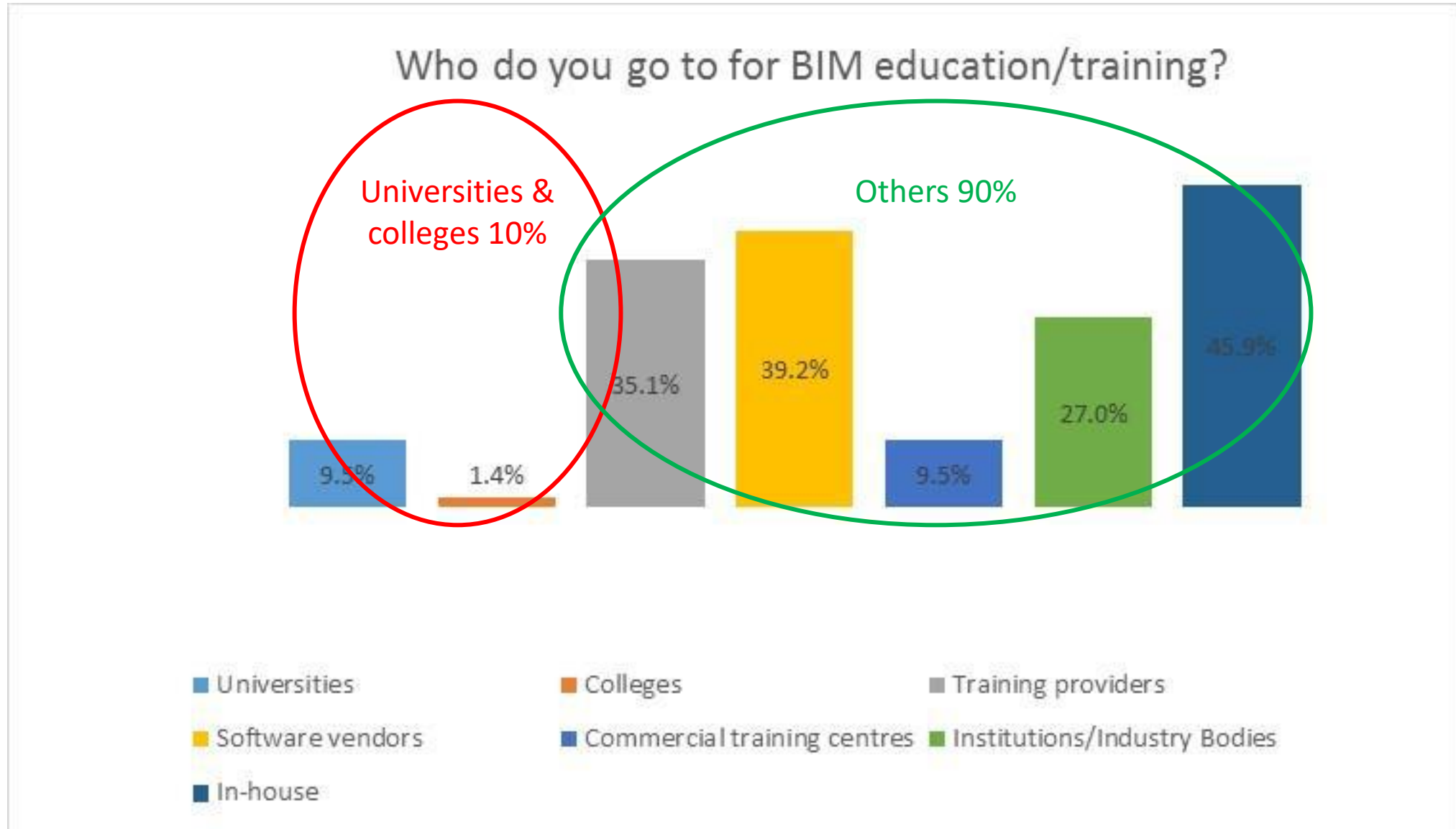
Continuing Professional Development - CPD

- Large number of BIM CPD courses are provided by professional associations, universities and commercial companies
- Content and level are very diverse, from ½ day BIM introductions to long courses for specific professionals

Solving recruitment problems, medium-long term

Which of the following would help solve recruitment problems in the medium-long term? Please select all that apply.

44.6%   55.4%

- 23.0% — Post-graduate courses
- 31.1% — Apprenticeships
- 21.6% — Undergraduate courses
- 24.3% — Sandwich courses

Legend:
- Apprenticeships
- Sandwich courses
- Undergraduate courses
- Post-graduate courses

Source: Internal Report for BRE BIM Prospects 2016
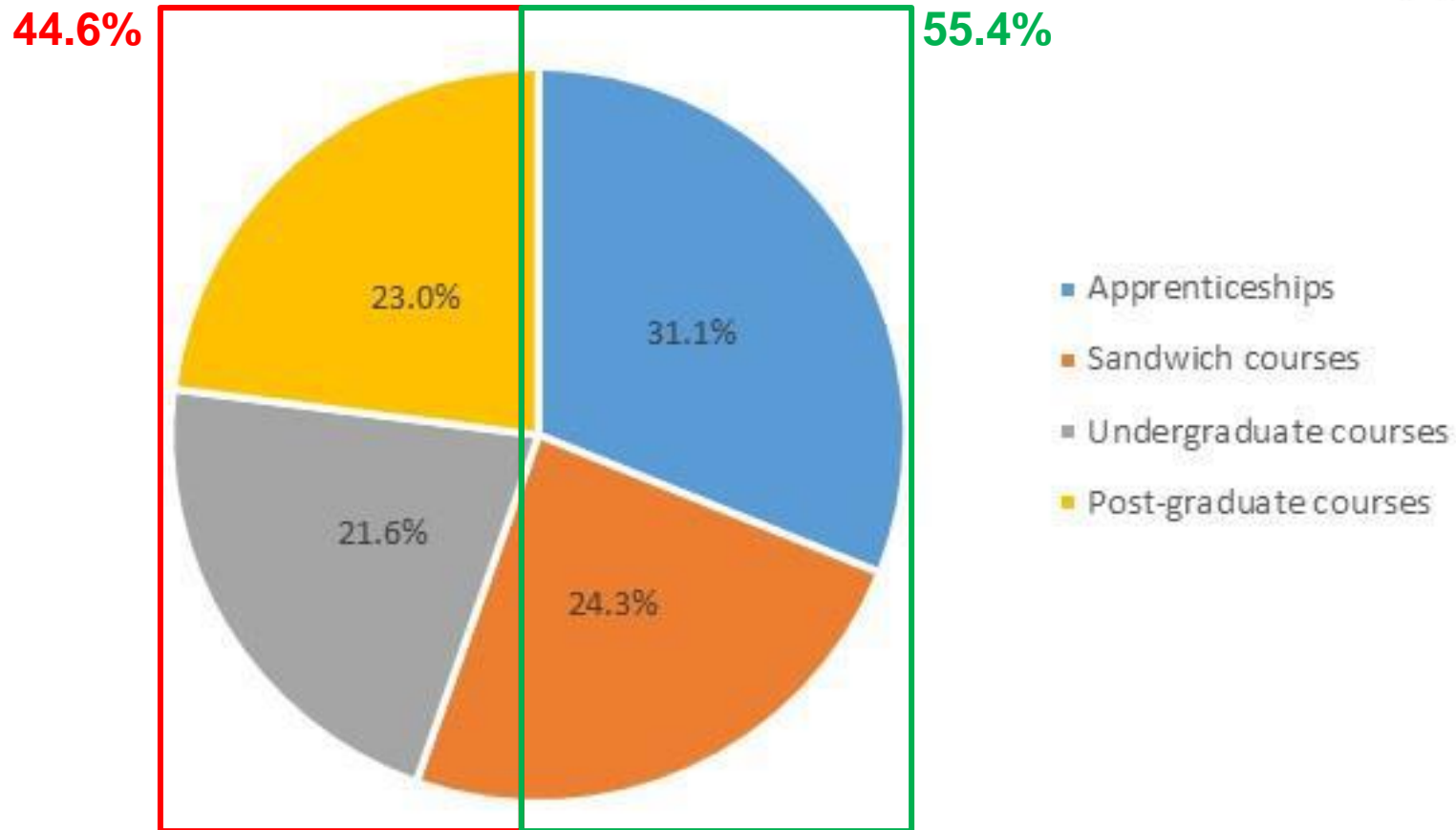
Some conclusions from the BRE report

- **Education is clearly not producing the BIM skilled candidates needed by industry now.** As BIM adoption accelerates (as it must to meet the government mandate in the UK), this situation will be exacerbated. **There has to be closer links between industry and academic institutions.** Requirements need to be defined and comprehensive courses developed.

- **SMEs, who lack the funds to finance employee training, would greatly benefit from 'BIM ready' industry entrants**.

Source: Internal Report for BRE BIM Prospects 2016

University BIM education

Focus should be in medium/long term,
not in training

200+ specialised BIM MSc programmes in UK

Embedding BIM within the taught curriculum

- A report by BIM Academic Forum (BAF) and supported by the Higher Education Academy is available @ https://www.advance-he.ac.uk/knowledge-hub/embedding-building-information-modelling-bim-within-taught-curriculum

Embedding Building Information Modelling (BIM) within the taught curriculum

Supporting BIM implementation and adoption through the development of learning outcomes within the UK academic context for built environment programmes

June 2013

The Higher Education Academy

BAF
BIM Academic Forum

Changing or replacing existing modules is difficult

- Changing existing curricula can be a very difficult and time consuming process
- Existing curricula are full of topics, there is simply no space for additional issues
  - **What can be left out?**
  - **Strong resistance from everyone whose expertise area's relevance is questioned**

BIM teaching impact matrix

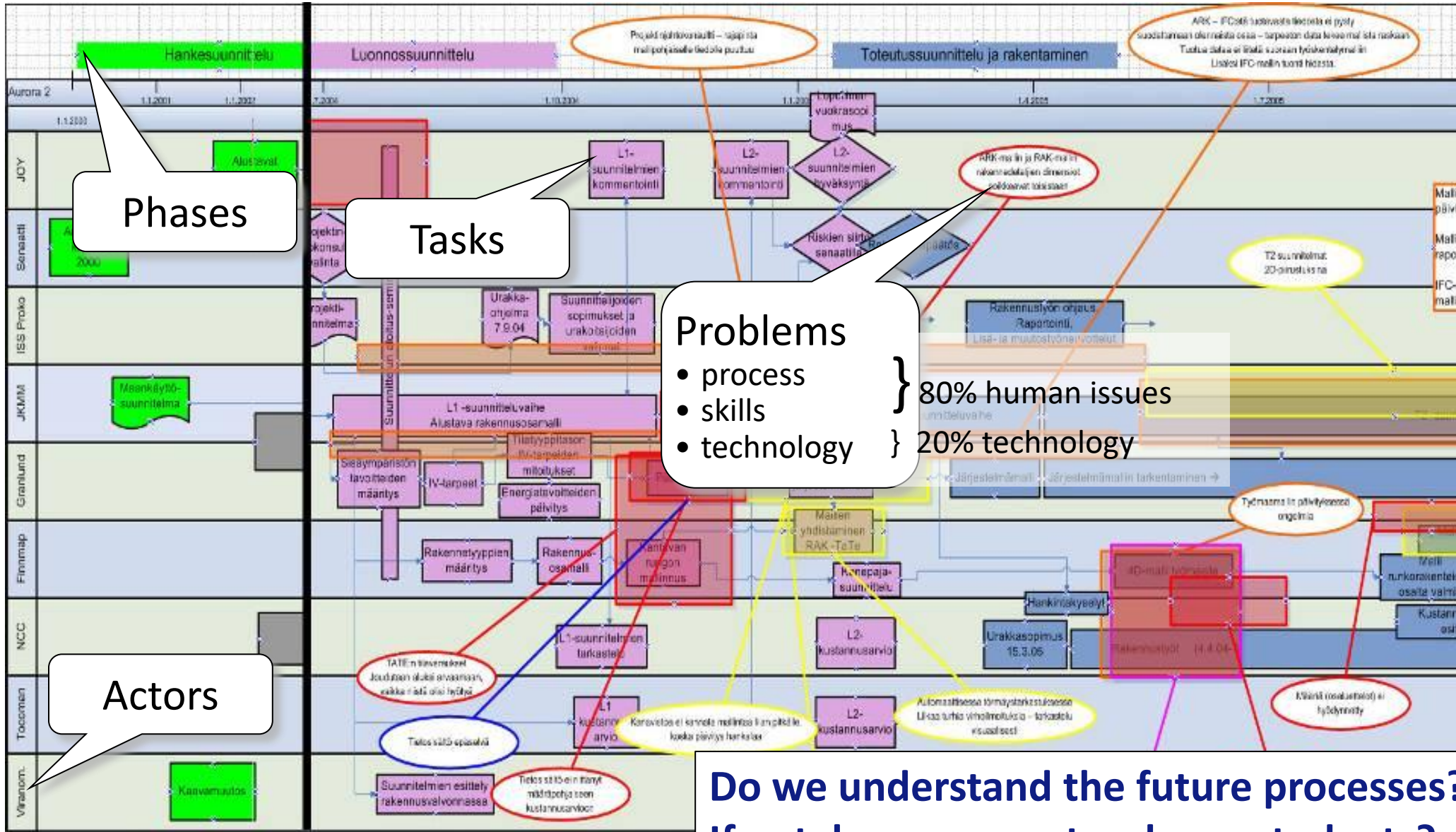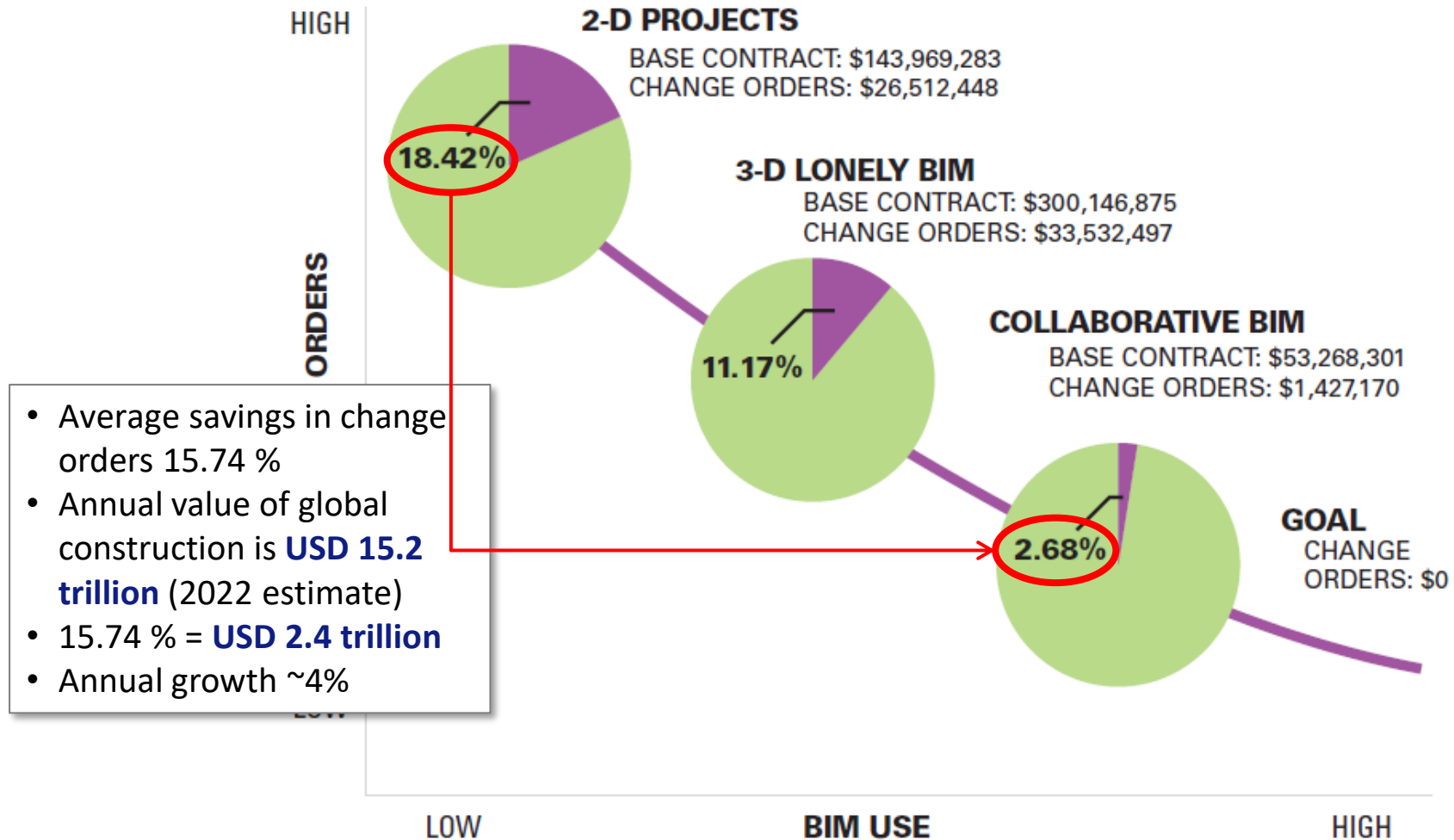|	BIM Level			
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should enabled by the BIM model.
Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.
Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
Staff	No change	Staff in the key modules will need an understanding of BIM and how it impacts of industry.	All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.	All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.
Infrastructure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/ delivery.

Source: BIM Academic Forum (UK 2013):
"Embedding BIM within the taught curriculum"

Skills & processes?

Expected Learning Outcomes

	Knowledge and understanding	Practical skills	Transferable skills
Level	*Undergraduate*		
4	- importance of collaboration - the business of BIM	- Introduction to technology used across discipli	- BIM as a process/technology/people/policy
5	- BIM concepts construction processes - stakeholders' business drivers - supply chain integration	- use of visual representations - BIM tools and applications - attributes of a BIM system	- value, lifecycle and sustainability - 'software as service' platforms for projects - collaborative working - communincation within inter-disciplinary teams
6	- BIM across the disciplines - contractual and legal frameworks/regulation - people/change management	- Technical know how: - structures and materials - sustainability	- Process/management: - how to deliver projects using BIM - information and data flows - BIM protocols/EIR
	Postgraduate		
7	- collaborative working, BIM, information management and its application in the built environment - commercial implications contractual/legal etc - de-risking projects through BIM and risk management - understanding nature of current industry practice - client value soft landings - business value RoI/ value proposition - understanding supply chain management - lifecycle management of BIM asset, performance in use etc	- demonstrate ability to adopt different platforms - critically judge/evaluate various BIM tools/applications - protocols/inter-operability/ standards - capability evaluation - change in way projects are to be delivered - visualisation of large data sets - lean principles and links to BIM - use of BIM enabled technology e.g. palm devices	- project level application - cross discipline and team working - importance of effective communication and decision making human interaction! - process mapping and BPR - change management and cultural gap - masters level thinking strategic/technical/ managerial - ability to assess barriers to BIM at various levels e.g. corporate/project

Need to analyse and re-think the data flows

Phases

Tasks

Problems
- process
- skills
- technology

} 80% human issues

} 20% technology

Actors

**Do we understand the future processes?
If not, how can we teach our students?**

Main benefits require collaboration

HIGH

ORDERS

2-D PROJECTS
BASE CONTRACT: $143,969,283
CHANGE ORDERS: $26,512,448

18.42%

3-D LONELY BIM
BASE CONTRACT: $300,146,875
CHANGE ORDERS: $33,532,497

11.17%

COLLABORATIVE BIM
BASE CONTRACT: $53,268,301
CHANGE ORDERS: $1,427,170

2.68%

GOAL
CHANGE ORDERS: $0

- Average savings in change orders 15.74 %
- Annual value of global construction is **USD 15.2 trillion** (2022 estimate)
- 15.74 % = **USD 2.4 trillion**
- Annual growth ~4%

LOW   **BIM USE**   **HIGH**

A study by J.C. Cannistraro of 408 projects Valued at $559 million shows how, in the big picture, BIM saves money as the team gets more collaborative.

Problematic dependencies and timing

- In real projects there are a lot of dependencies between different disciplines, and in the integrated BIM environment it is crucial to understand how these affect the workflow.

- However, having the real dependencies in education is very problematic. If one student does not deliver on time or the quality is not sufficient, we cannot punish other students because the bad marks would be a burden for the rest of their career, not just in that one project. **How to simulate the dependencies without negative effects?**

- In addition, **what is the right stage to teach collaboration?** How much the students have to know about their own discipline before learning their role in the team?
  - According to Pihlak et al (2011) the **collaboration across different disciplines was productive only when designers were strong and confident.**
  - Too much compromise led to less than optimal design solutions.

Kocaturk, T. & Kiviniemi, A. (2012) Challenges of Integrating BIM in Architectural Education

Technology vs. business?
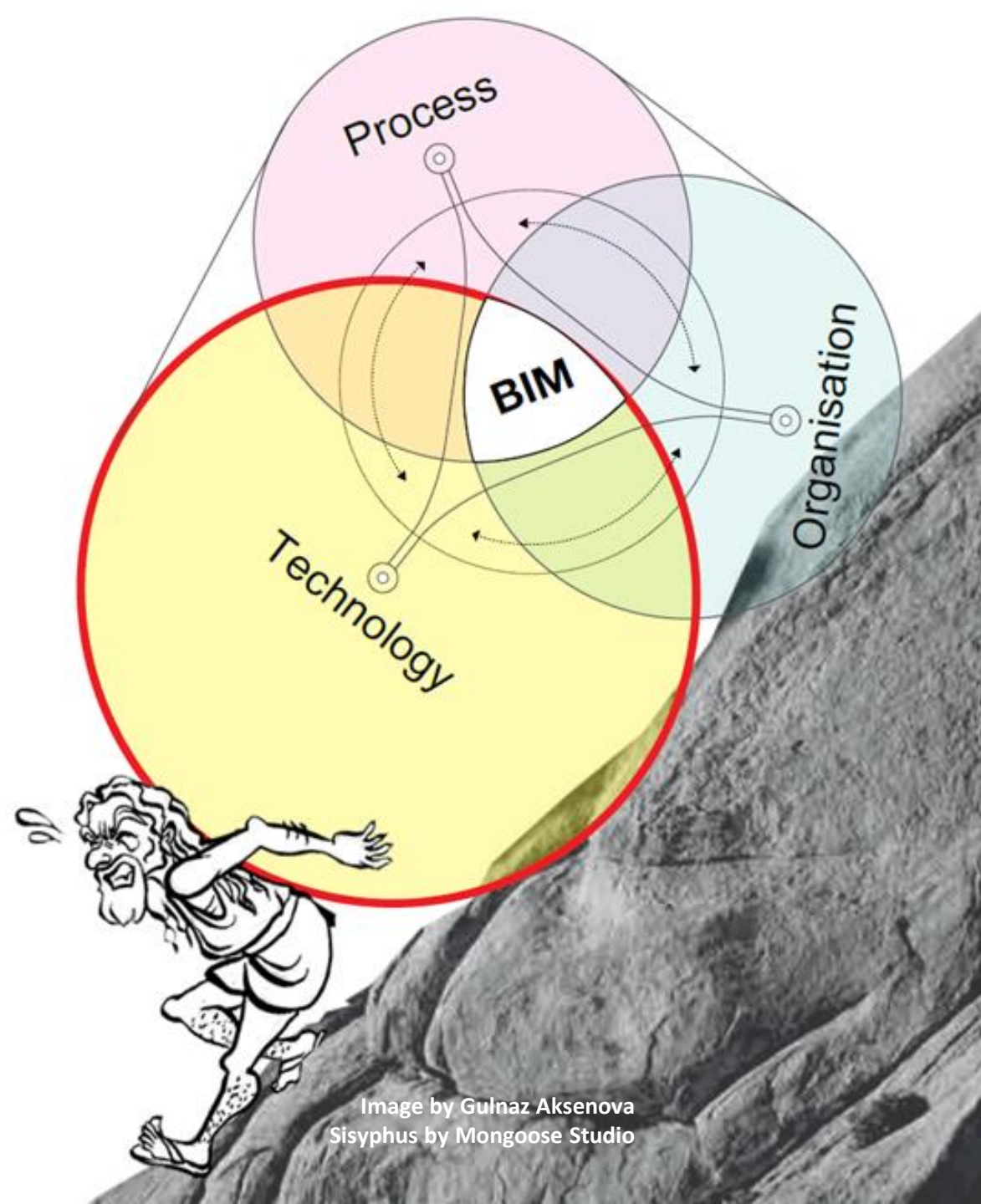
The question is **NOT** about technology!

Image by Gulnaz Aksenova
Sisyphus by Mongoose Studio
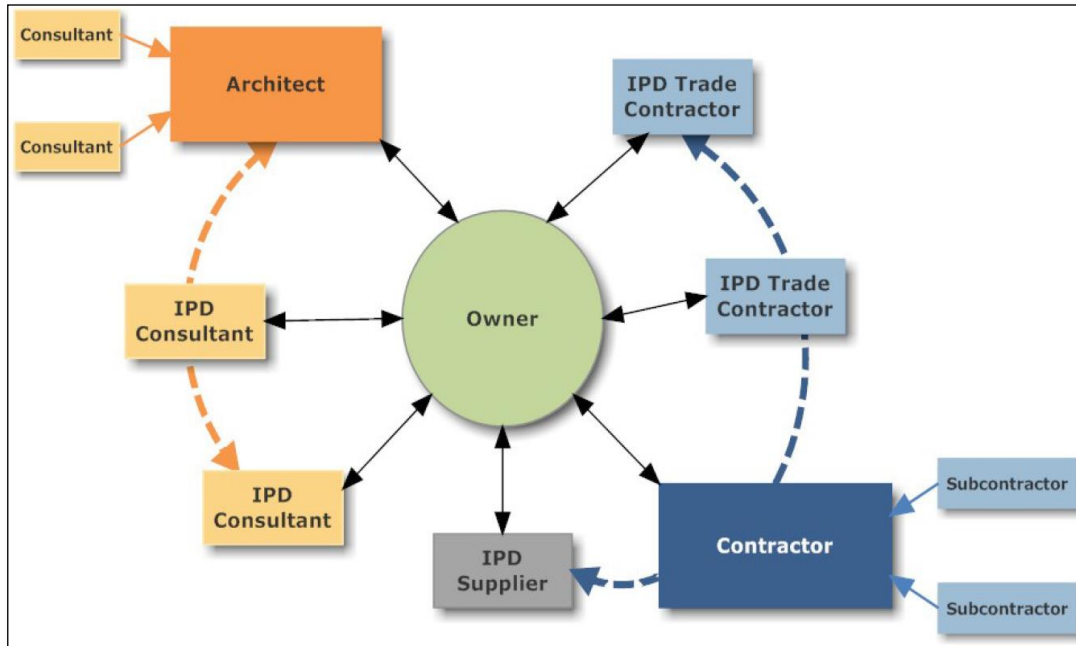
Ivan Krylov: Swan, Pike and Crayfish (1814)

How do we align the goals?

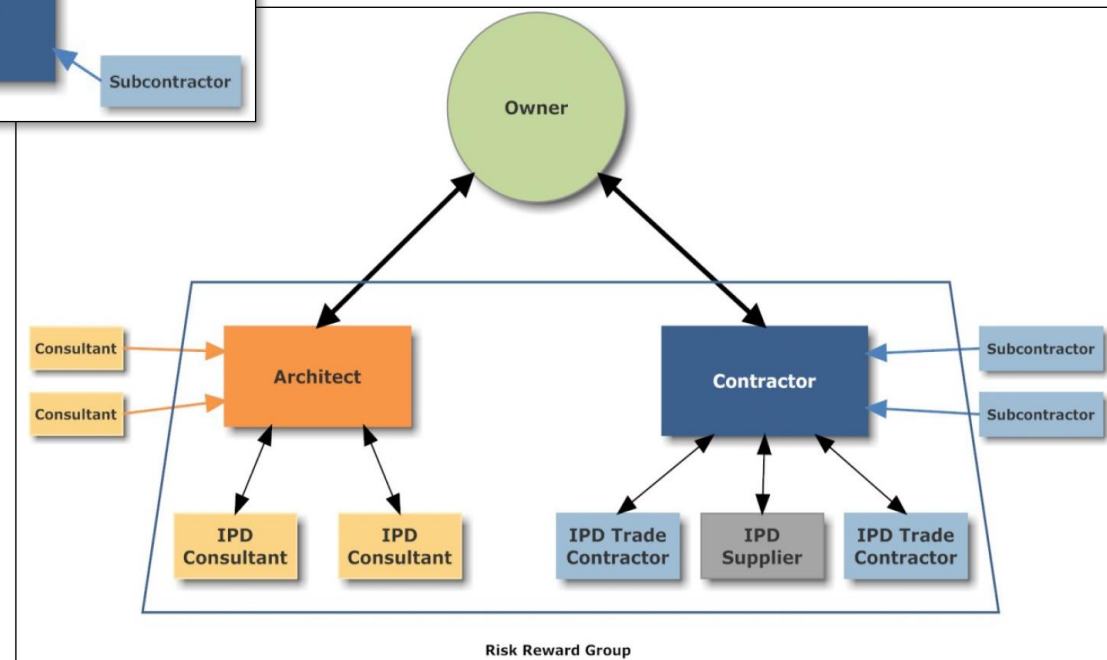Gulnaz Aksenova, one of my former PhD students

Need for new contractual models, e.g. IPD

"Sharing the pain and the gain"

Polyparty contract

Multiparty contract

Risk Reward Group

Source: HansonBridgett: The IPD Framework

Business models have changed radically …

Open source architecture?

Open Source Architecture

Carlo Ratti with Matthew Claudel

Pinecone House
Biloxi Model Home

F2/E

PAPERHOUSES
ARCHITECTURE IN OPEN SOURCE

OPEN SOURCE SUSTAINABLE ARCHITECTURE
www.OneCommunityGlobal.org/Duplicable-City-Center
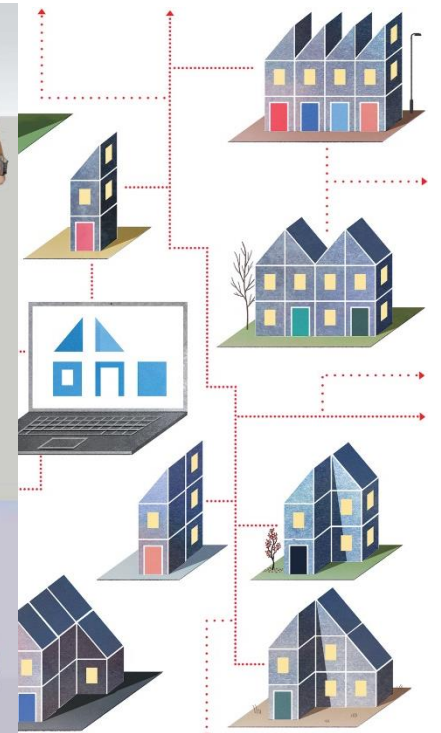
Customer value?

Focus on the lifecycle and business values

Client's core business

New needs

FM services

Change adaptation

Design & construction process

How can design improve the business performance of buildings?
Could we evaluate, validate and measure that?

Business = 400 - 2000

Design = 1

Construction = 10

Operation in 20 years = 30 - 50

Arto Kiviniemi – VERA programme 2000
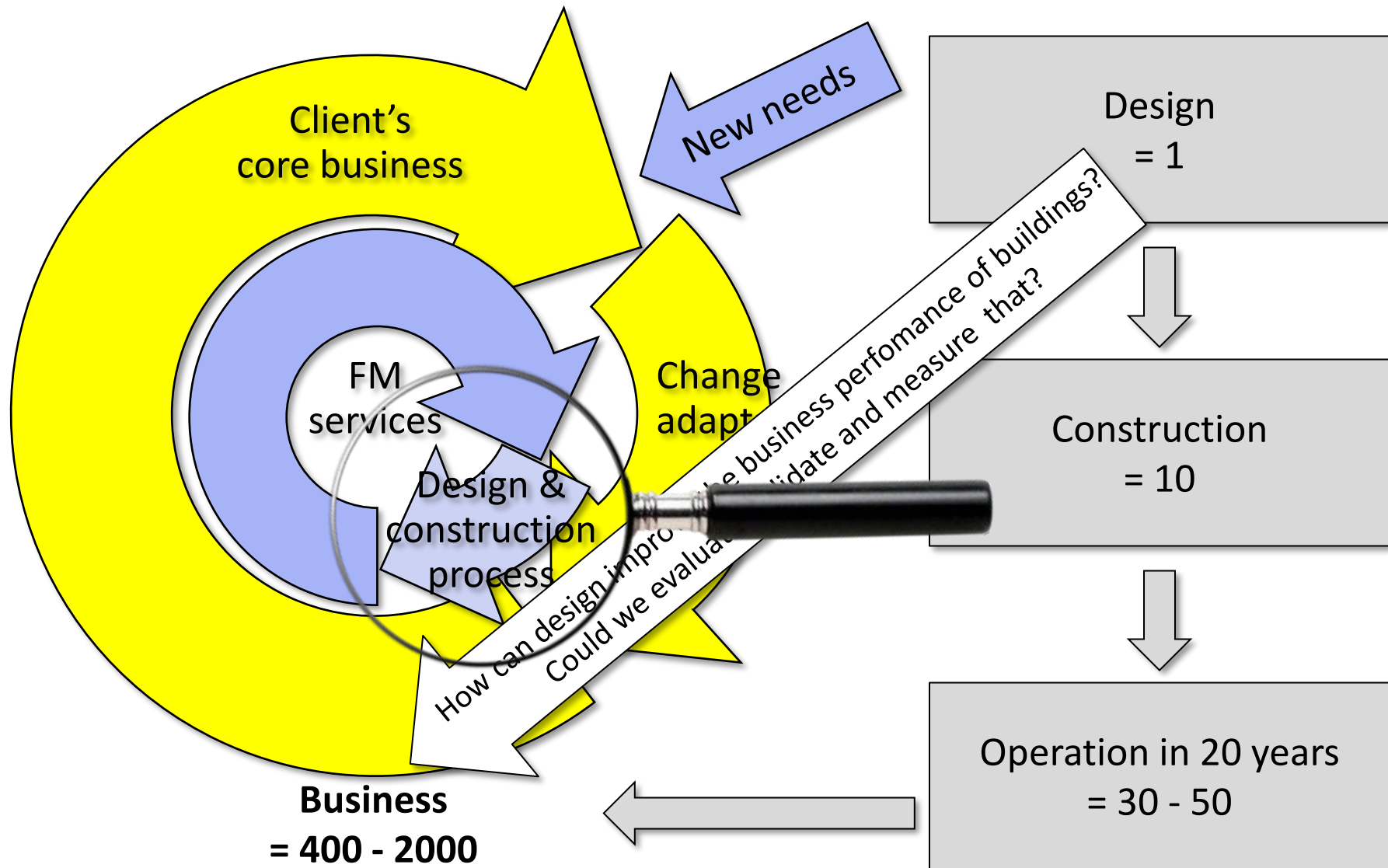
What do we mean by the performance of the buildings?

We should start simulating the **business performance** of buildings!

Usually we simulate the **energy performance** of buildings…

Fig. 20.2 Average annual office expenditure (Romm and Browning, 1994, p. 30).

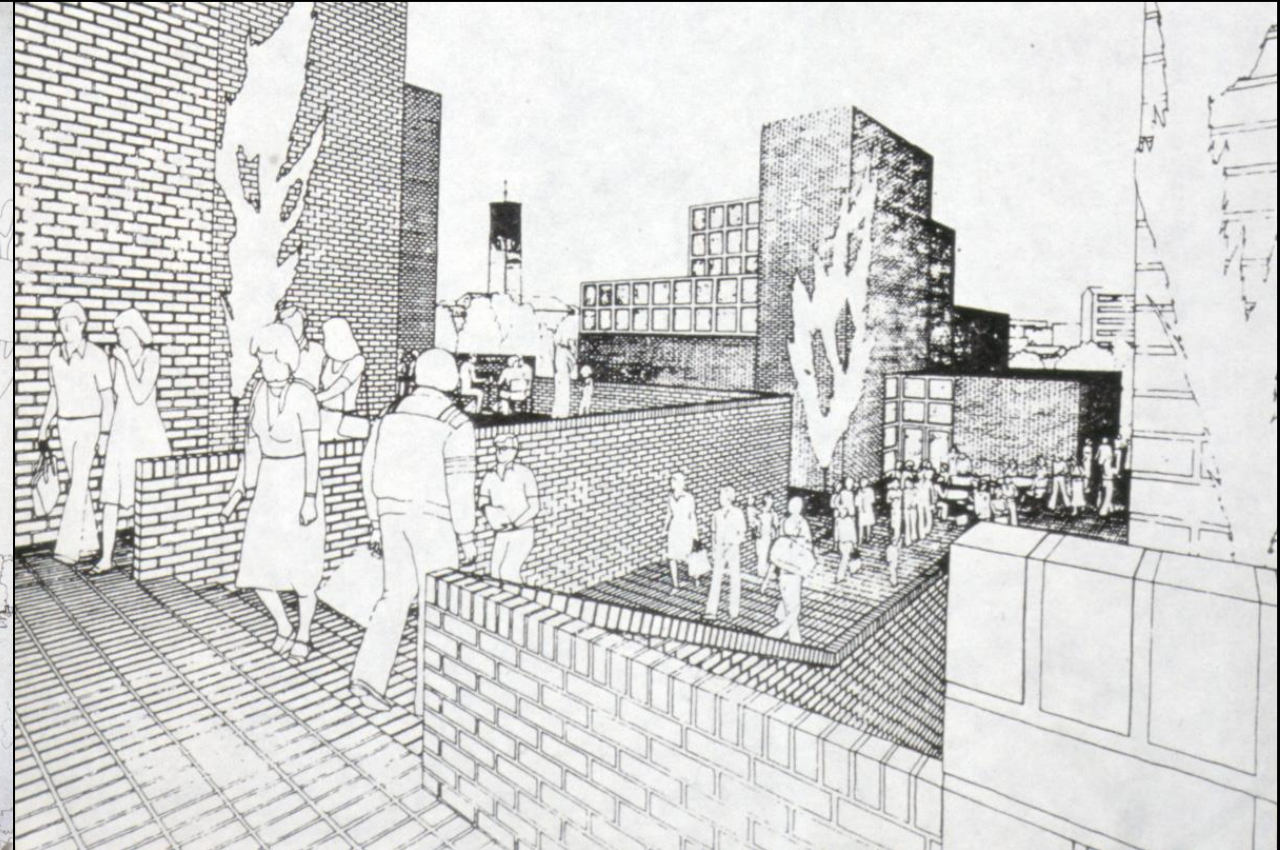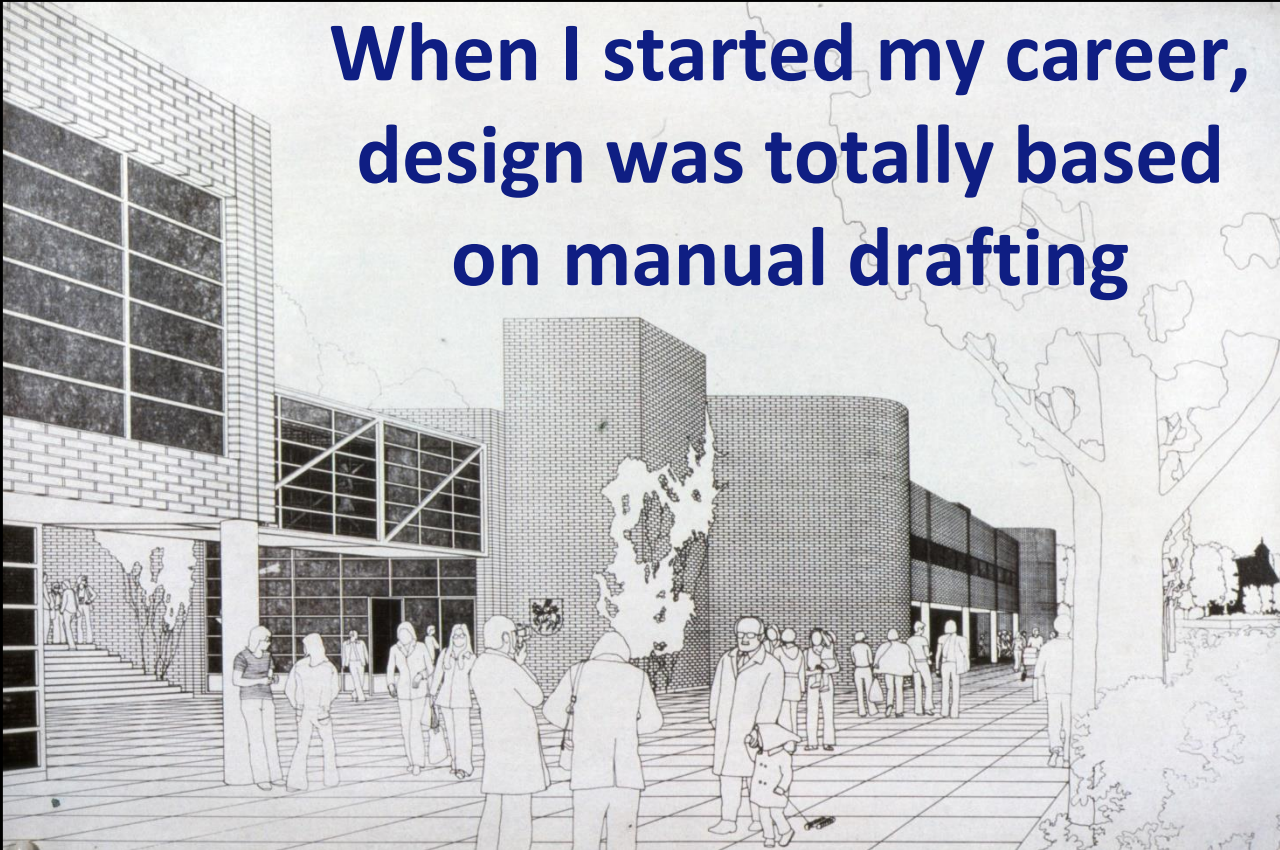Image: Beijing Airport baggage claim, SMART Solutions Buro Happold

Salaries	**92%**
Running costs	6%
Capital cost	2%
Total energy	**1.3%**

Rick Best, Gerard de Valence (1999)
Building in Value: Pre-Design Issues

Communication?

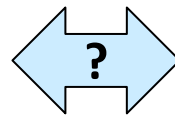When I started my career, design was totally based on manual drafting
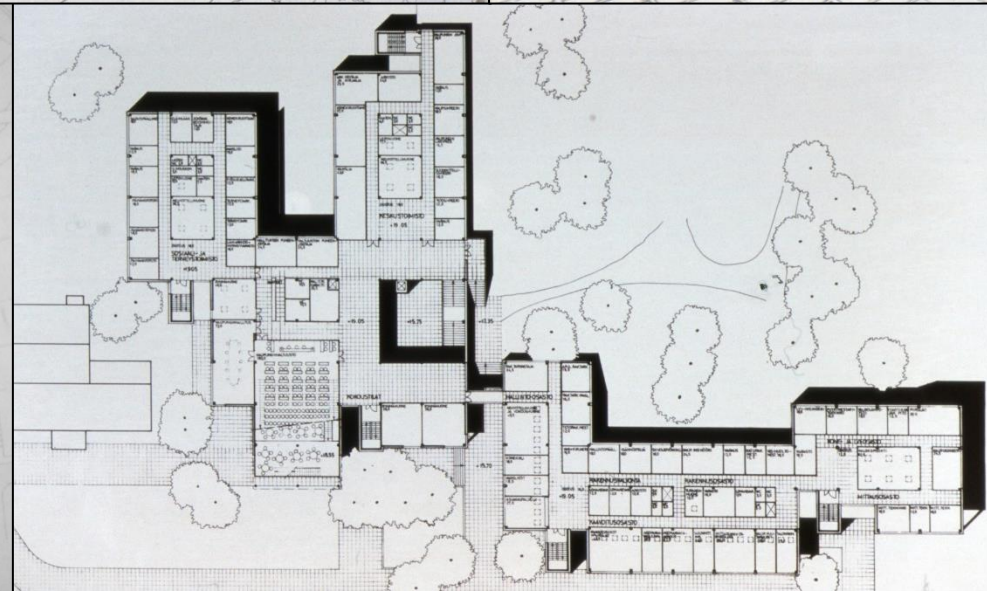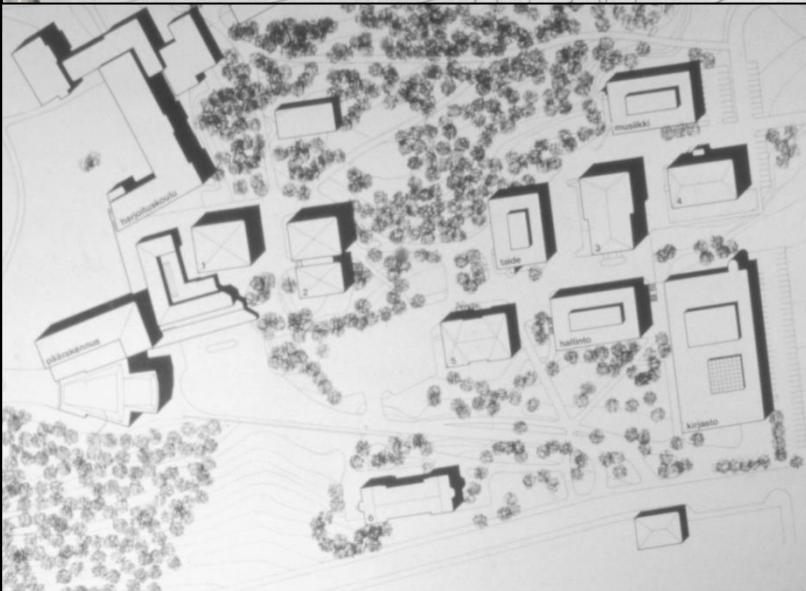
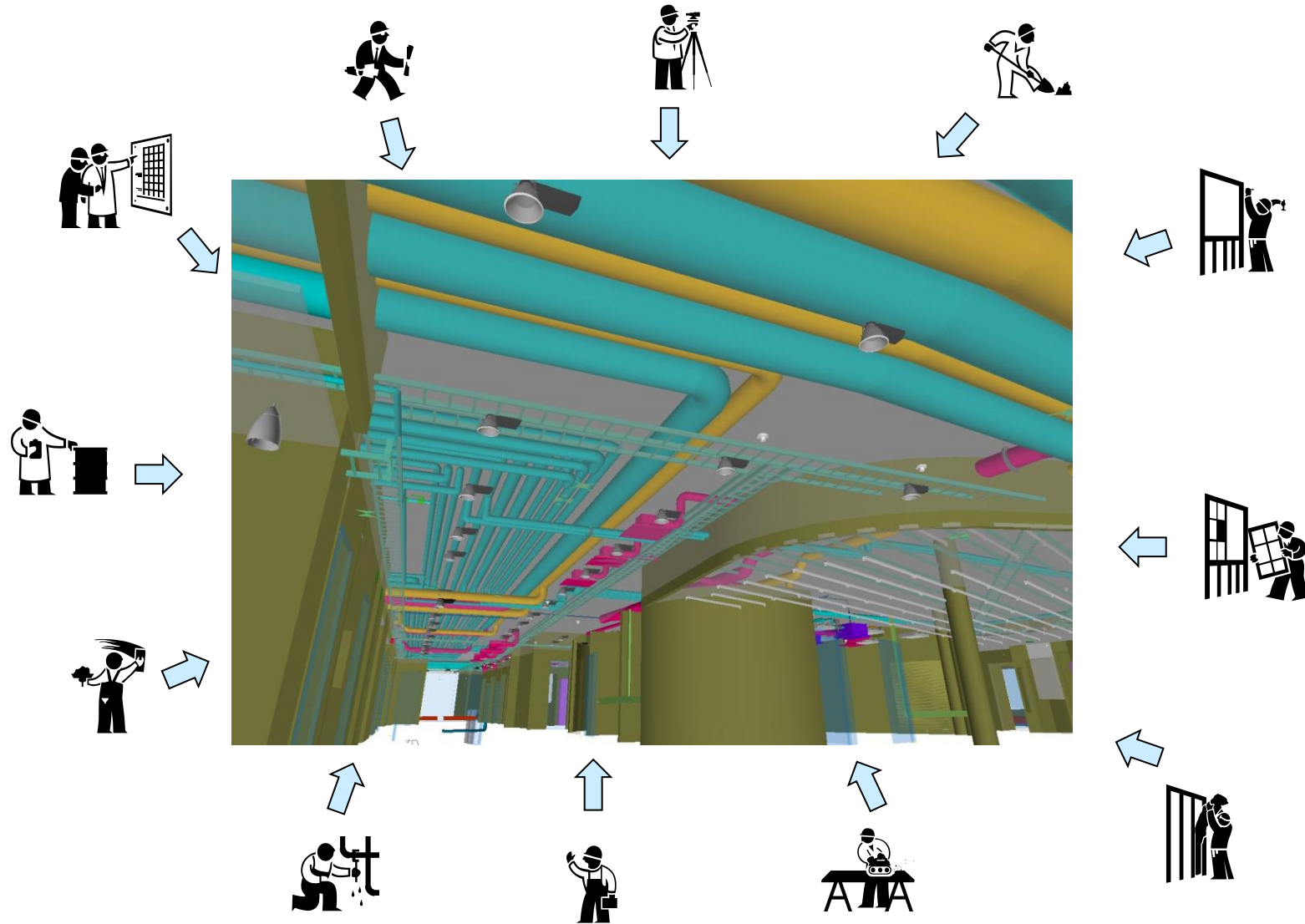# Robotics, 3D printing... how long do we need drawings?

Do we still need drawings?

- In paper-based environment drawings were the best way to communicate the building design.
- However, technical drawings are very high level abstraction of our 3D world and not easy to read for non-professionals – and even for professionals it is not easy to build a complex 3D space in their mind by reading drawings.

?

Document centric process = incoherent documents, different views and different abilities to understand

Better communication and shared understanding
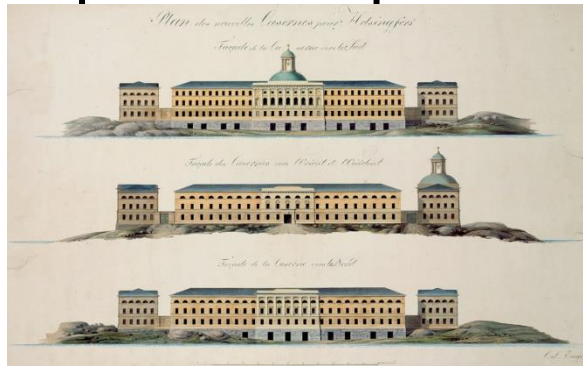
Image courtesy Granlund

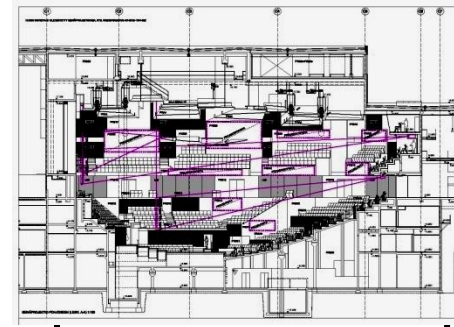# Media & thinking?

Media affects our thinking

Design by experience - physical models

Manual drafting and tracing, highly illustrative drawings

Drawings required for building permit (in Finland)

Back to the illustrative representation

Integrated BIM

Manual drafting, copying machines, simplified/abstract representation

Early CAD = automated drafting

Modelling
Interoperability
Simulation
Collaboration platforms
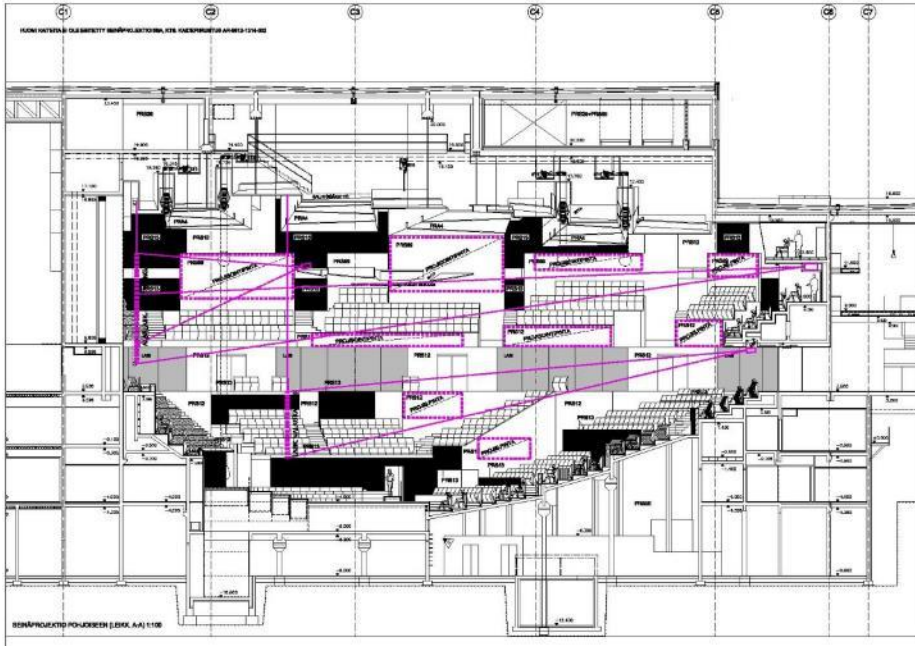Virtual prototyping

1775   1900   1985   2000   2010

Architectural education is still often based on drafting and other traditional documents

- Most teachers are experts in 2D drafting, some in 3D modelling, but relatively few in BIM
 - Lot of friction, in worst case active resistance in moving to 3D

- Curricula are full of topics, there is no space for additional issues
  - **What can be left out?**
- Developing new or changing existing curricula can be a very difficult and time consuming process

Learning the visual language

- Designers do not just learn to make drawings; **they learn to think through drawings**
  (Daniel Fällman 2003)
  - Unlearning is a painful effort; when learning a new media a design expert becomes a novice
  - ⇨   Focus shifts from content to the tool
  - Significant loss of efficiency and creativity until the new media becomes an integral part of the designer's mind-set
- Older generation cannot avoid that, but **why are we forcing our students to go through that pain?**
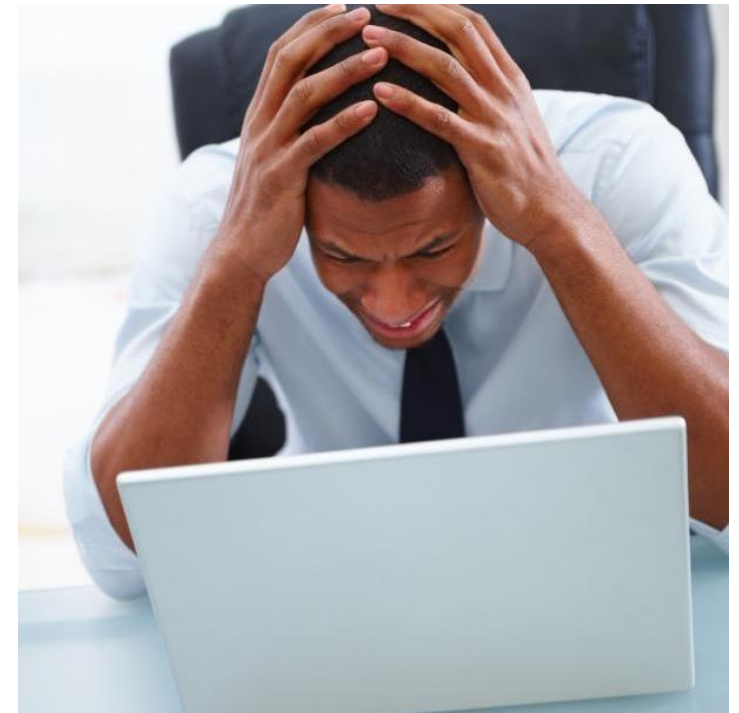
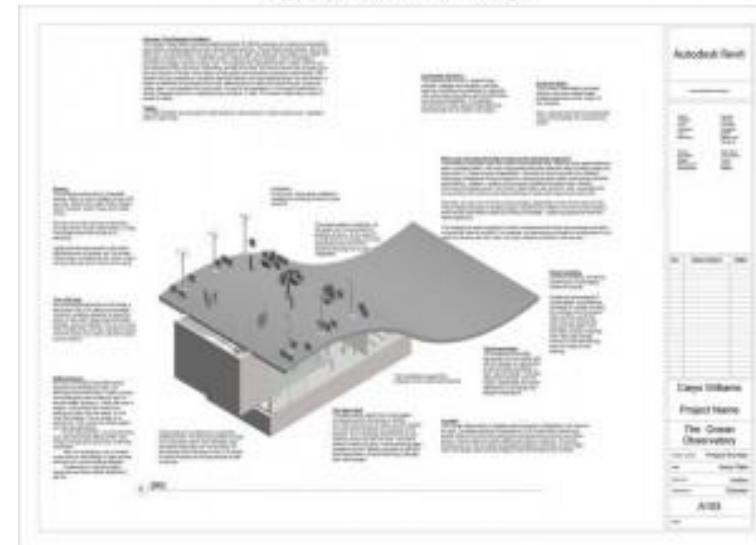# The young generation has grown up with 3D software...
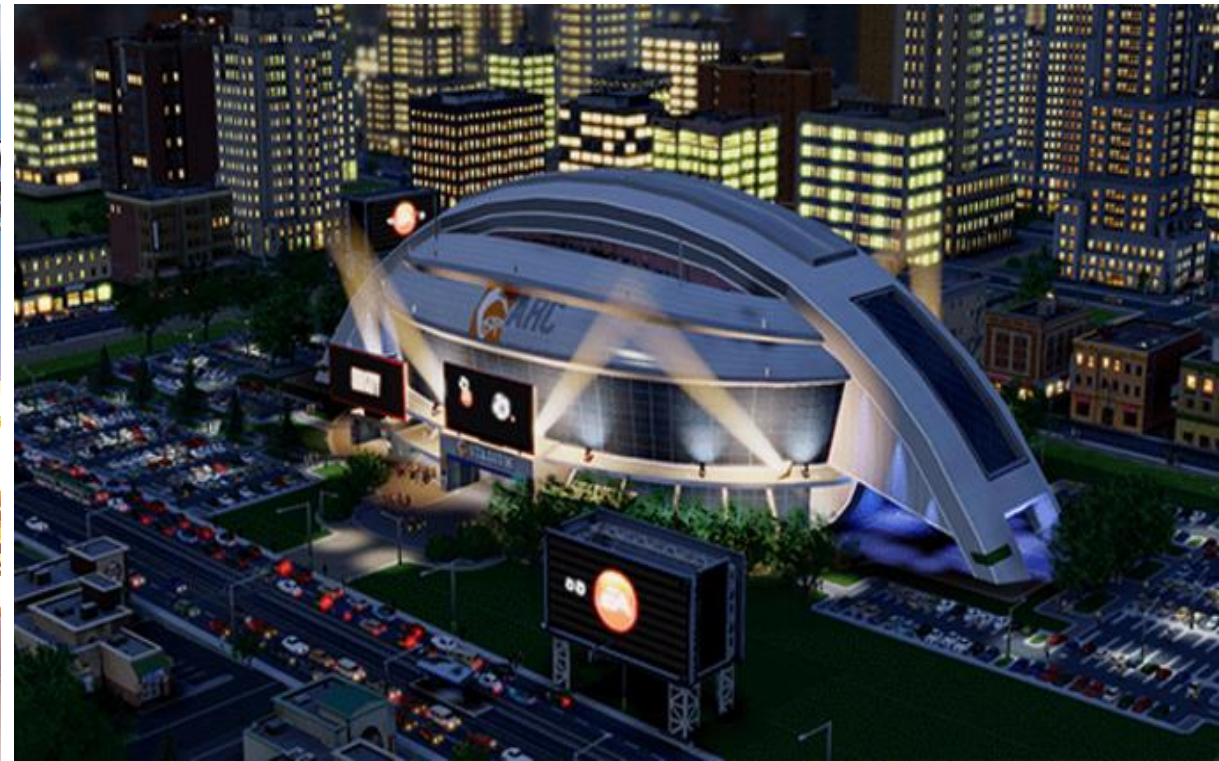
…even school kids can easily learn how to use BIM

School of the Future Competition 2012

classofyourown®

The Ocean Observatory
Highfield Humanities College

Are we teaching issues in the right order?

Often we forced students first into 2D and allow 3D only later.
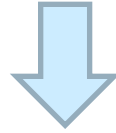
Are we teaching issues in the right order?

Should we teach 3D first and then how to generate 2D views from the models?

What is a model?

What is a model?

- A model represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality. Jeff Rothenberg "AI, Simulation & Modeling" 1989

- Different domains (architectural design, structural and HVAC engineering, construction tasks, FM...) have different models because they perform different tasks.

- The shared models must cover (at least) the parts necessary for the desired purpose(s) such as design coordination.

- However, defining the content and representation in a homogeneous way is not a simple task because the content and representations in different domain models are very different.

Does BIM kill creativity?
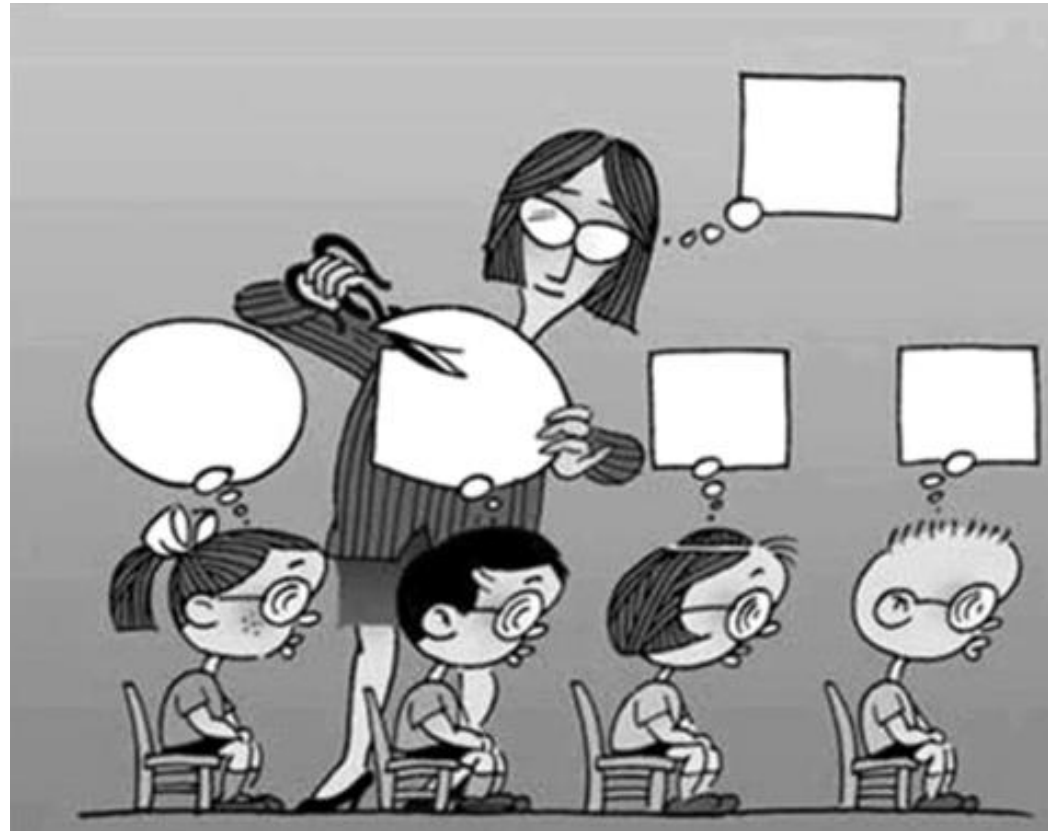
In the nature material is
expensive and shape is free.
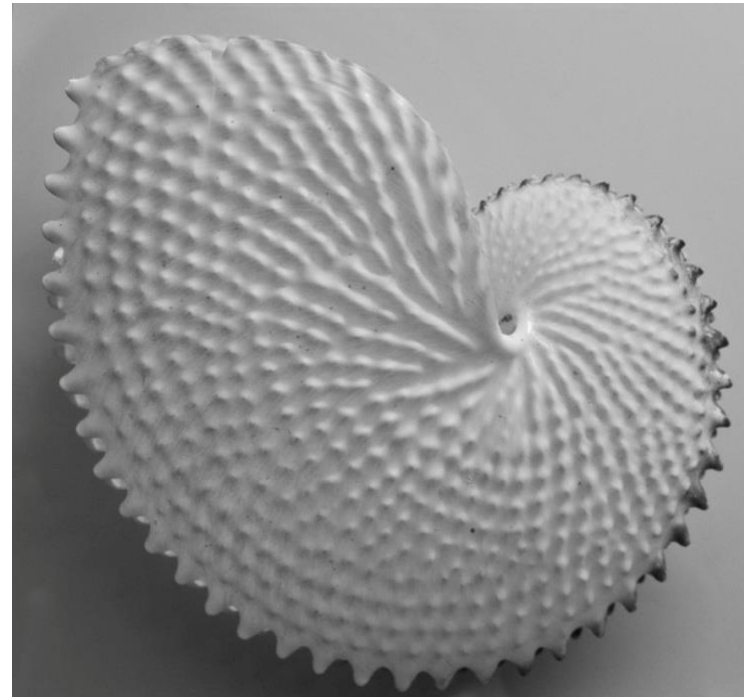
Inspired by Prof Julian Vincent's Biomimetics

In the nature material is
expensive and shape is free.
**In the traditional construction shape
is expensive and material is cheap.**

Inspired by Prof Julian Vincent's Biomimetics

In the nature material is
expensive and shape is free.
In the traditional construction shape
is expensive and material is cheap.
Is it likely that in the future shape
will be cheap and material expensive?
Printing complex forms is not a problem!

© Dr Arto Kiviniemi 2022

Inspired by Prof Julian Vincent's Biomimetics

Conclusions

- We have to analyse our processes and **identify the valuable core** of the different professions and separate it from "old rubbish" – issues that are outdated, but we still teach them just because we learned them ourselves.

- Instead of traditional documents we must bring into our education system new issues, such as lifecycle information management, enhanced communication and collaboration, new production methods, and other possibilities of the modern technologies.