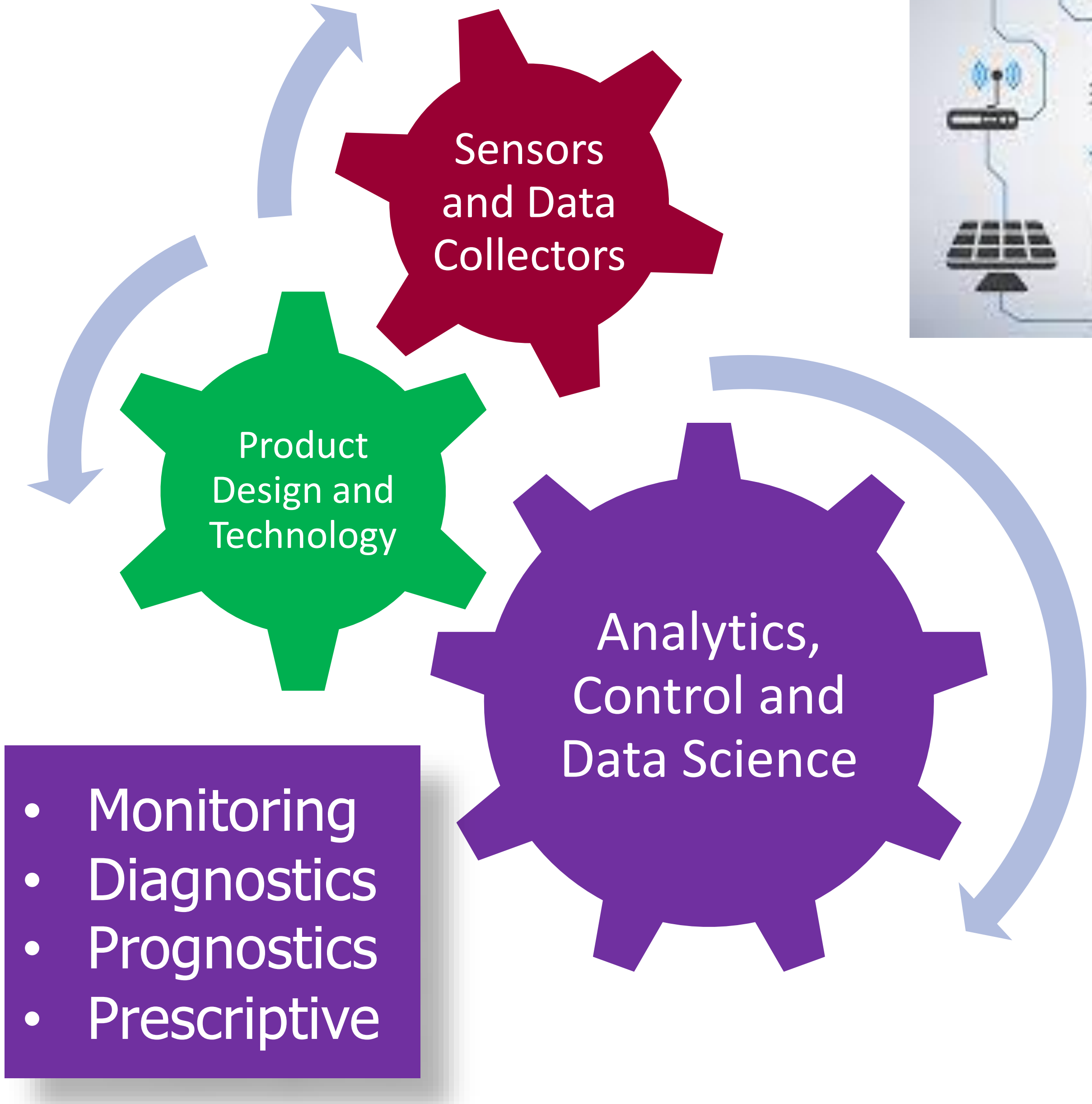
https://youtu.be/bGHIGBK-zjc

Data science educational challenges: supporting lifelong learning objectives with hybrid simulation platforms

Ron S. Kenett and Mark Bailey

Agenda

- The challenge
- Simulations and education
- Assessing understanding
- Some examples
- Impact on JMP education



Sensors and Data Collectors

Product Design and Technology

Analytics, Control and Data Science

- Monitoring
- Diagnostics
- Prognostics
- Prescriptive

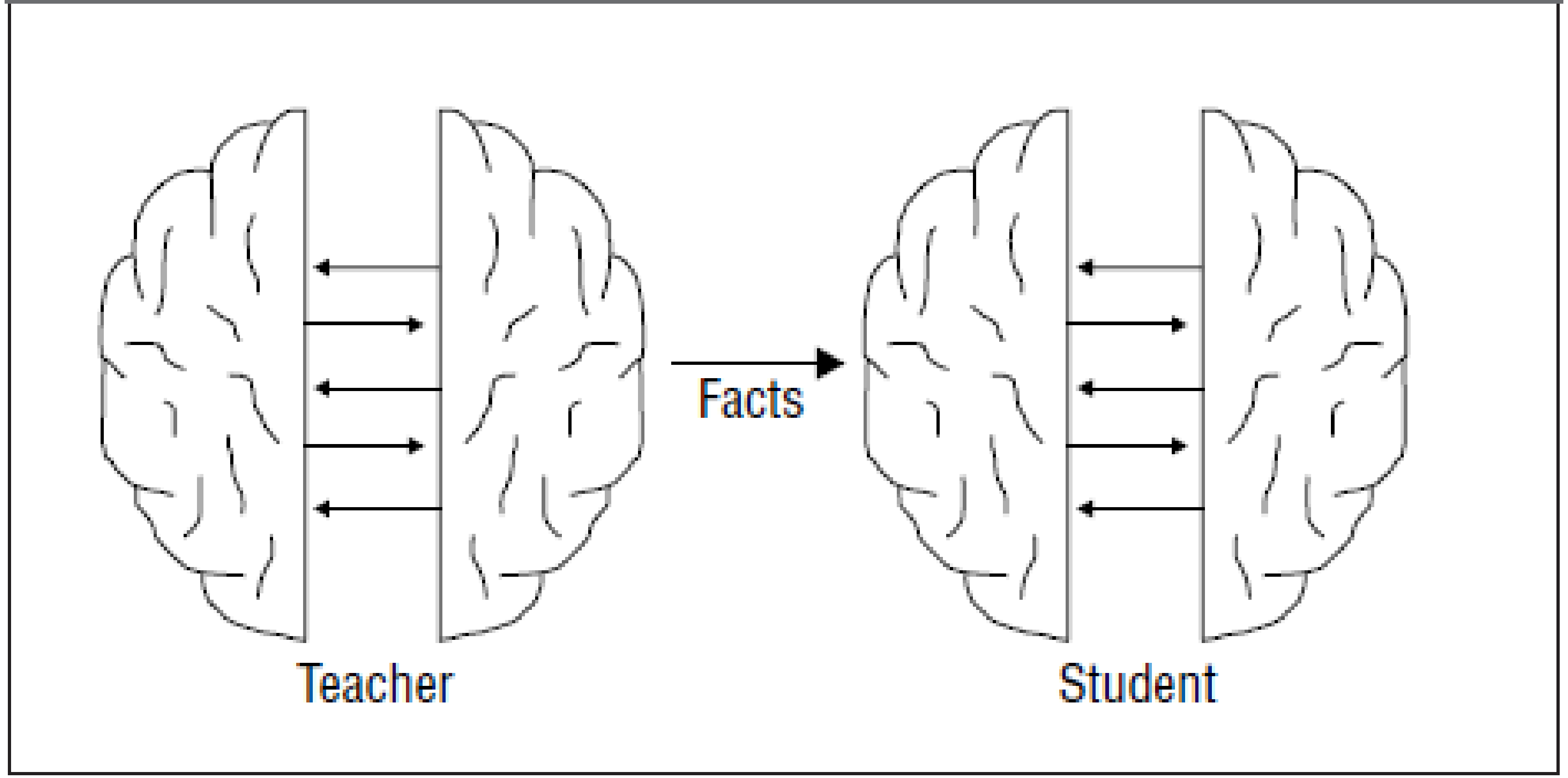
Deployment of analytics

1. Addressing a need
2. Using proper methods
3. Having adequate infrastructures
4. **Providing the right skills to the right people**

The “Is” model of teaching

All models
are wrong,
but some
are **useful**

Figure 2. Traditional Method of Teaching



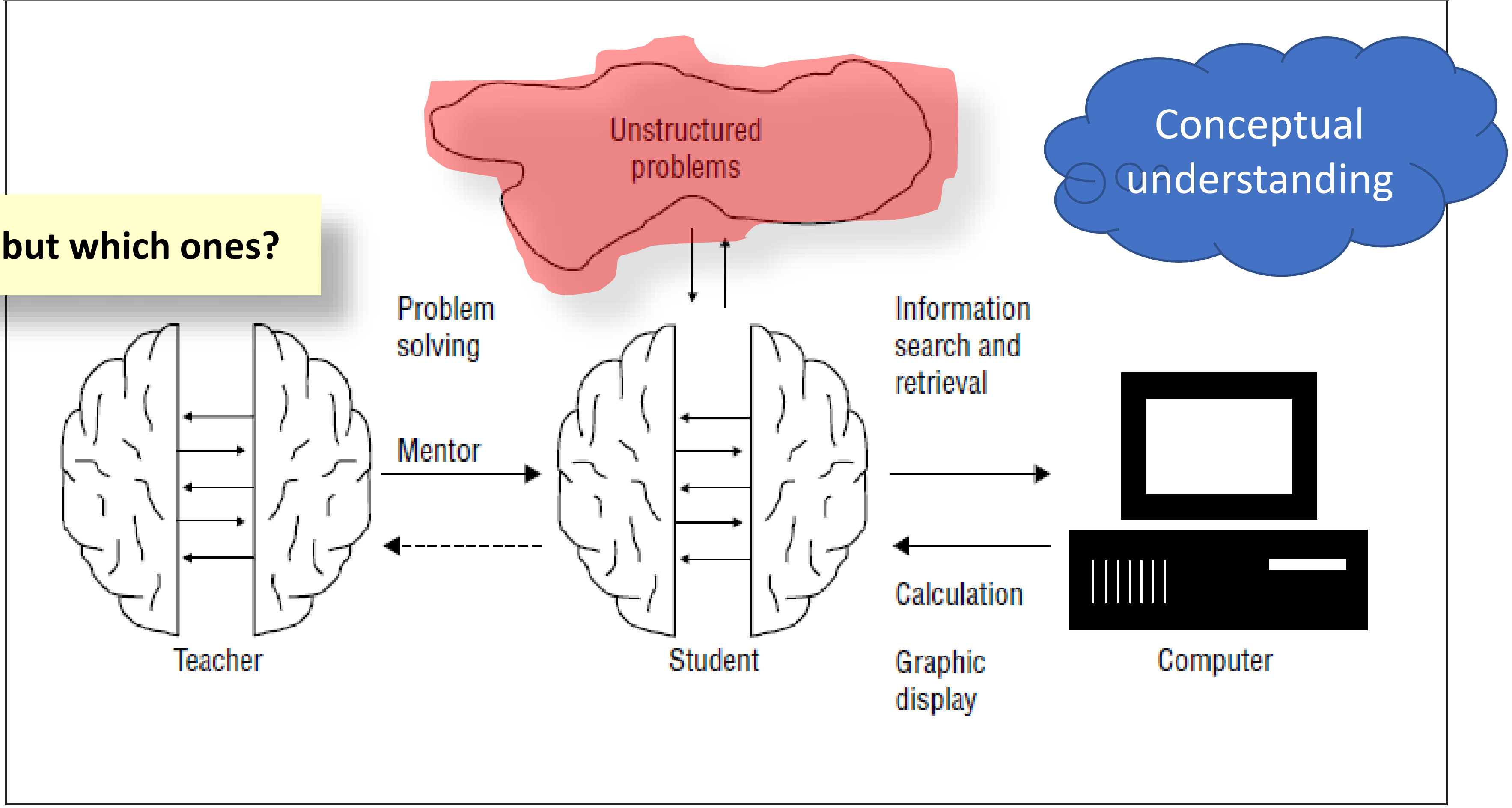
George Box (1997), Scientific Method: The Generation of Knowledge and Quality, *Quality Progress*, January, pp. 47-50.

The “Should” model of teaching

All models
are wrong,
but some
are **useful**

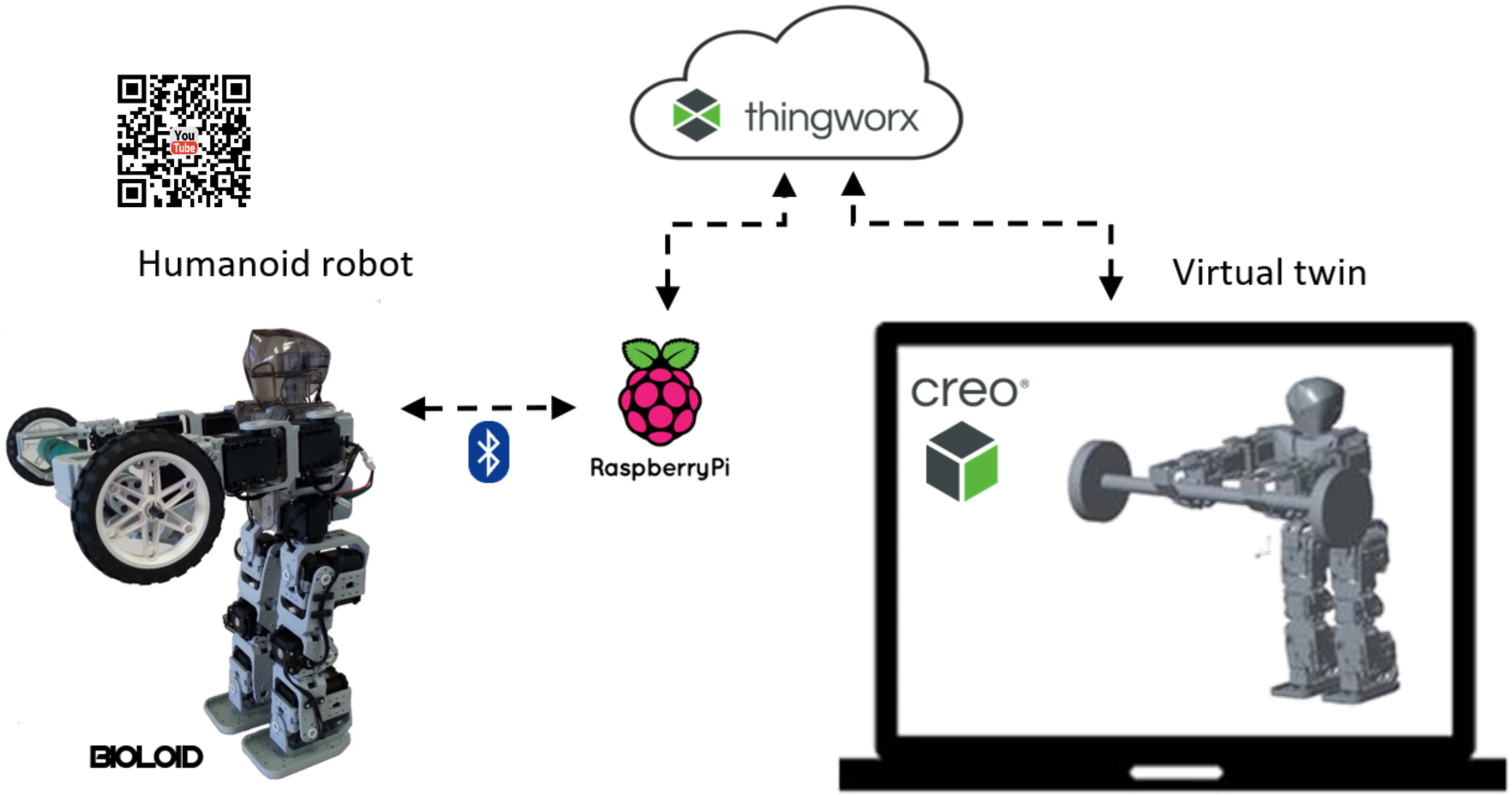
Yes, but which ones?

Figure 3. A Model for Modern Teaching



George Box (1997), Scientific Method: The Generation of Knowledge and Quality, *Quality Progress*, January, pp. 47-50.

Teaching robotics with a digital twin



Teaching objectives are conceptual:

- Data fusion
- Online monitoring
- Diagnostics
- Predictive analytics
- Condition Based Maintenance

A digital twin is a CAD model calibrated to accurately simulate the geometrical and physical properties of the robot. The twin learns to lift weights and shares the acquired knowledge with the robot through IoT.

https://intelitek.com/

https://intelitek.com/

Training Platforms

Industry 4.0 Classroom

Hands-on Real Industrial Trainers for Educational Programs

Standalone, small integrated platforms or full scale manufacturing trainers are offered by Intelitek to upgrade or start a new Industry 4.0 manufacturing training program. Integrating state-of-the-art systems teach core skills

Curriculum & E-Learning

Industry 4.0 Curriculum

New courseware addresses new skills specific to Industry 4.0 to broaden learning experience

The new technologies that enable Industry 4.0 are not typically taught in legacy programs. Networking, Data Science, Integration, IIoT to name a few, together with courseware focusing on

Certification

Industry 4.0 Certification

Micro-credentials and Student Certification provide validation of skills

Aligned with emerging ARM blueprint for Industry 4.0 Training Certification and in partnership with state and industry training leaders, Intelitek offer the content and framework for Industry 4.0 Certification.

Partnerships

Industry 4.0 Partners

Partnered with industry leaders, Industry vendors, education and institutions

Industry 4.0 is a collaborative technology and working with industry stewards like ARM, leading vendors like Yaskawa, Cognex, Siemens and more, manufacturers, state and government, and of course, educational institutions is

Handbook of Research on Applied Learning Theory and Design in Modern Education

Teaching and assessment of conceptual understanding

Chapter 15

Learning in the Digital Age with Meaning Equivalence Reusable Learning Objects (MERLO)

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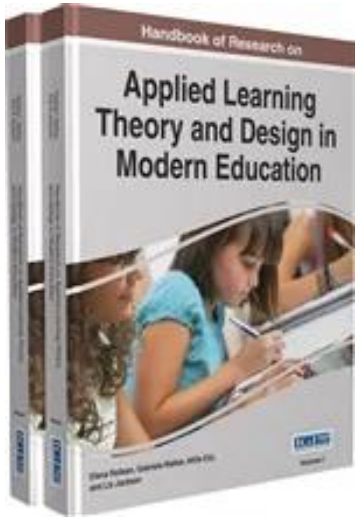
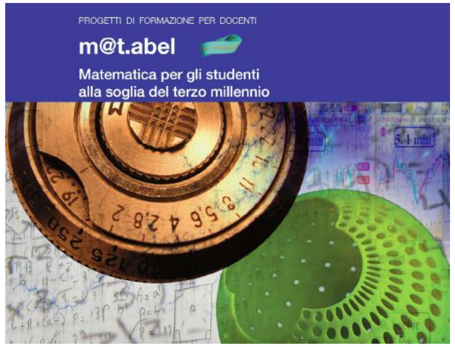
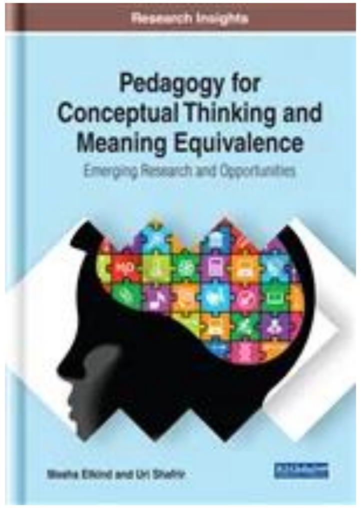
Ryerson University, Canada

Ron S. Kenett
KPA Group Ltd., Israel & University of Turin, Italy

Uri Shafrir
University of Toronto, Canada







Chapter 4

Teachers Involved in Designing MERLO Items

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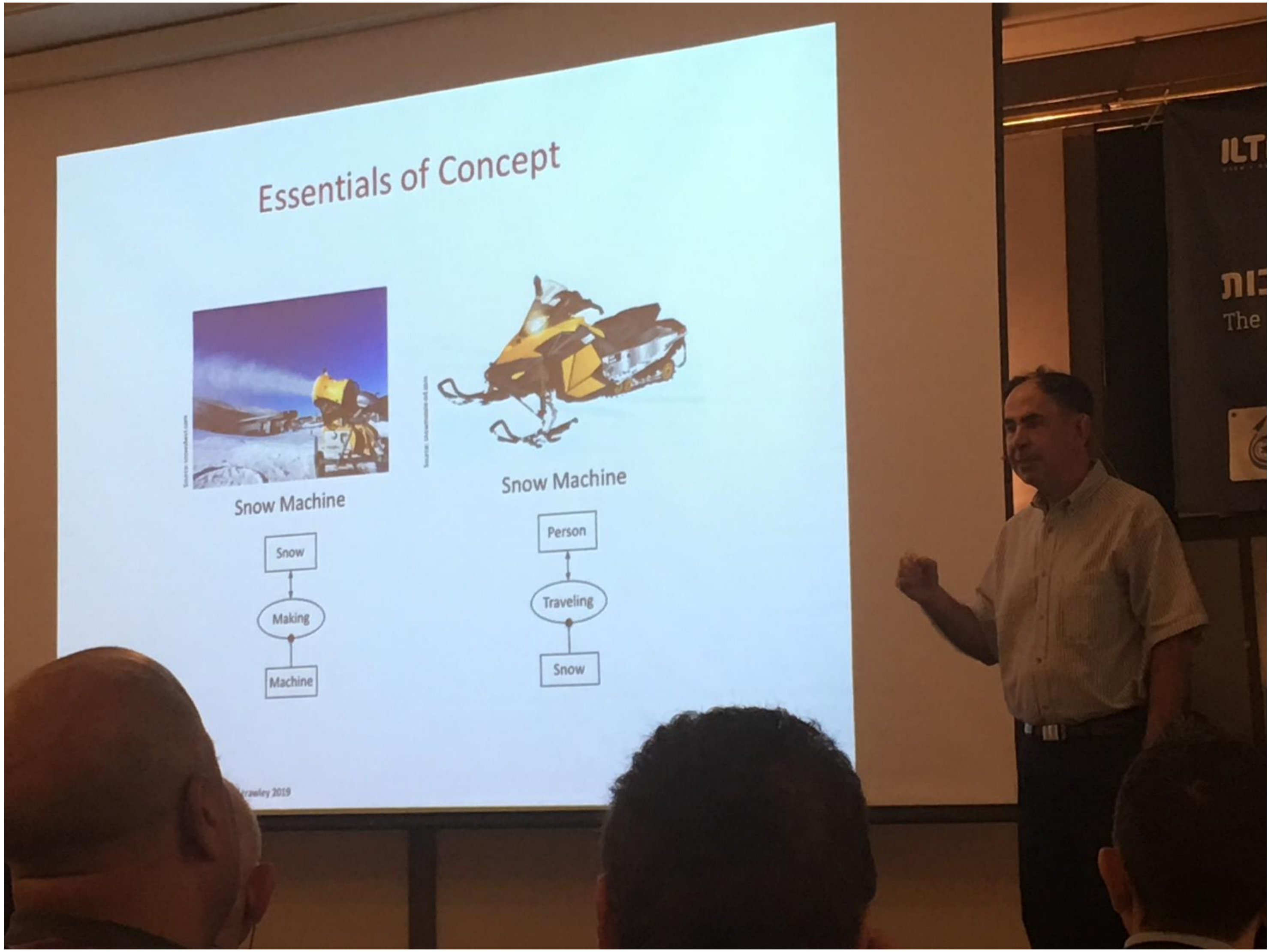
Università di Torino, Italy

Paola Carante
Università di Torino, Italy

Theodosia Prodromou
University of New England, Australia

Ron S. Kenett
The KPA Group and the Samuel Neaman Institute, Technion, Israel

Conceptual understanding in engineering:
the snow machine



Massachusetts
Institute of
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Edward F. Crawley

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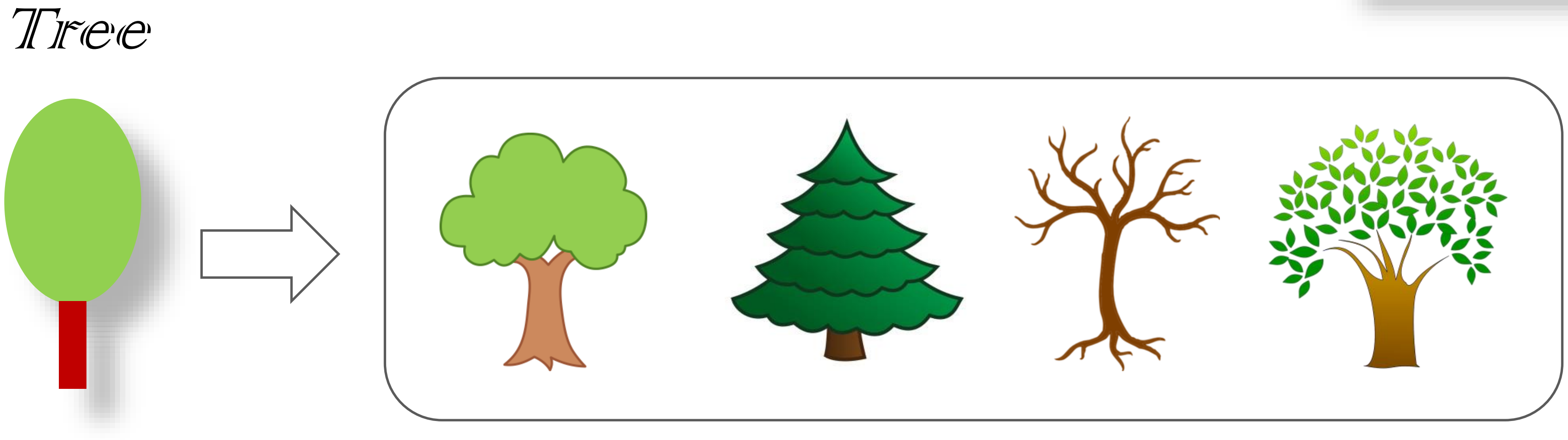
“A **concept** is an abstraction or generalization from experience or the result of a transformation of existing concepts.”

Wikipedia

Alternative representations



A concept can be represented in alternative forms

Meaning equivalence reusable learning objects (MERLO)

Four types of alternative representations

Surface similarity [SS]

Yes **No**

Meaning equivalence [ME]

Yes

No

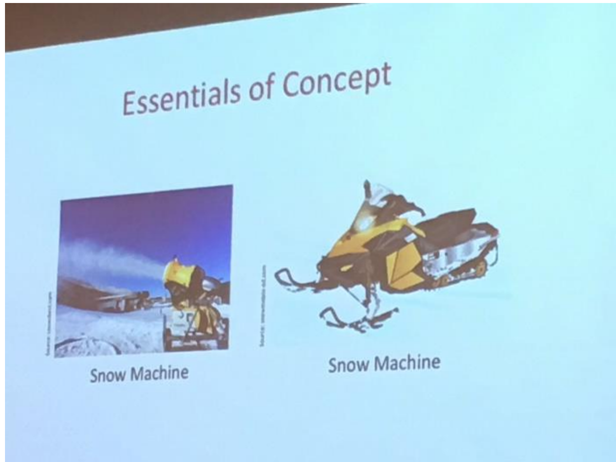
Q1

SS Yes
ME Yes

Q2

SS No
ME Yes

Q3



Essentials of Concept

Snow Machine

Snow Machine

Q4

SS No
ME No

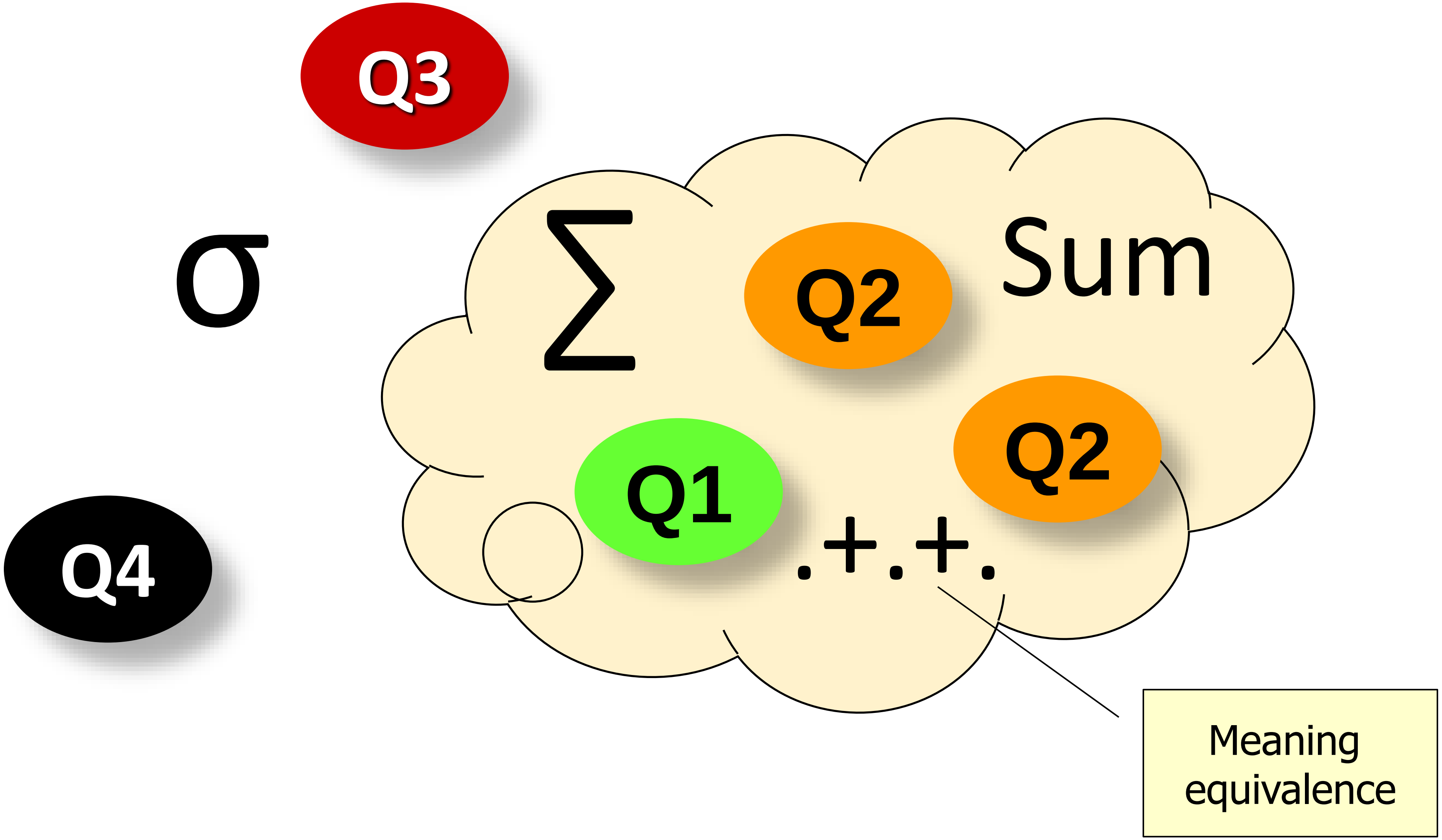
Q3

Surface similarity

σ ∑

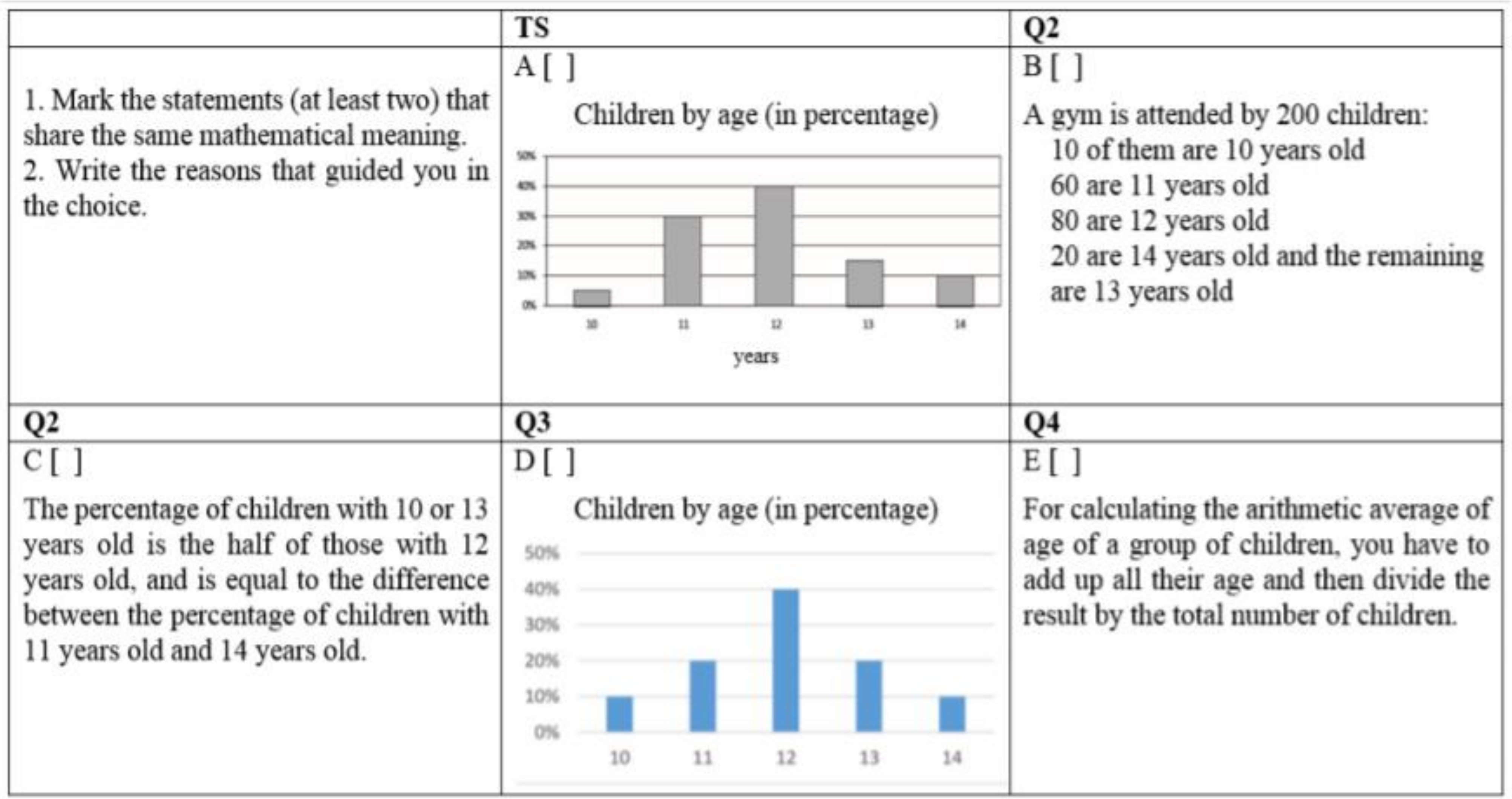
https://www.linkedin.com/pulse/little-sigma-big-sounds-same-has-totally-different-meaning-kenett/

Boundary of Meaning (BOM)



Assessing Conceptual Understanding

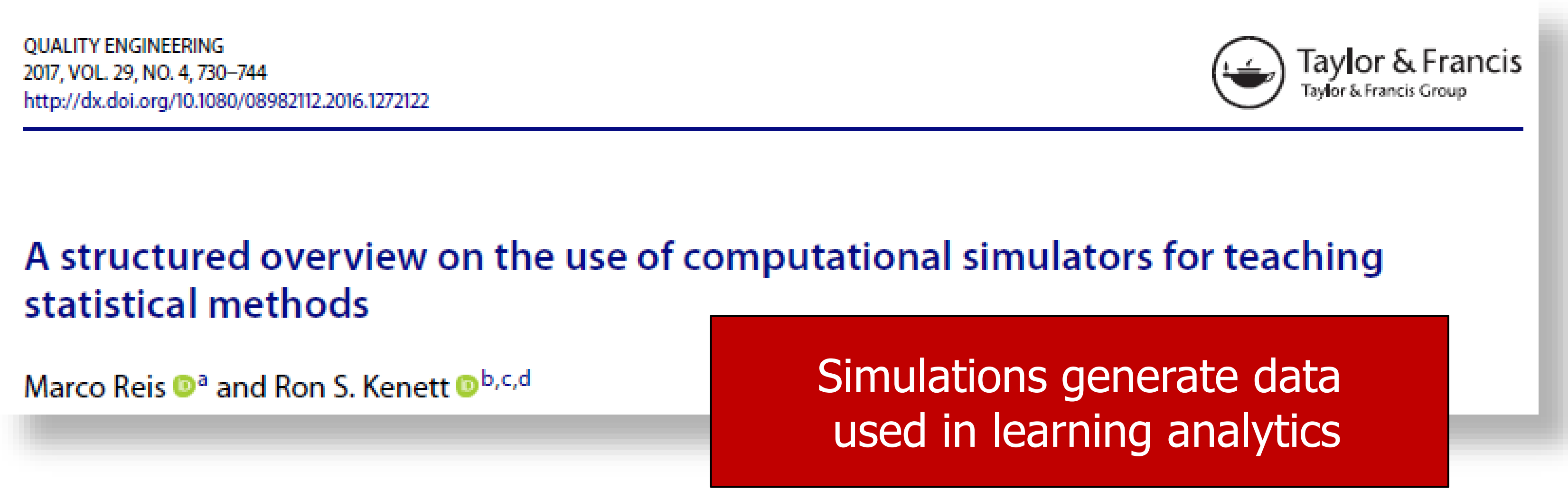
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3862006



	TS	Q2
1. Mark the statements (at least two) that share the same mathematical meaning. 2. Write the reasons that guided you in the choice.	A [ ] Children by age (in percentage) 50% 40% 30% 20% 10% 0% 10 11 12 13 14 years	B [ ] A gym is attended by 200 children: 10 of them are 10 years old 60 are 11 years old 80 are 12 years old 20 are 14 years old and the remaining are 13 years old
Q2	**Q3**	**Q4**
C [ ] The percentage of children with 10 or 13 years old is the half of those with 12 years old, and is equal to the difference between the percentage of children with 11 years old and 14 years old.	D [ ] Children by age (in percentage) 50% 40% 30% 20% 10% 0% 10 11 12 13 14	E [ ] For calculating the arithmetic average of age of a group of children, you have to add up all their age and then divide the result by the total number of children.

Classification Scheme for Simulation Platforms used in Education

https://www.tandfonline.com/doi/abs/10.1080/08982112.2016.1272122



QUALITY ENGINEERING
2017, VOL. 29, NO. 4, 730–744
http://dx.doi.org/10.1080/08982112.2016.1272122

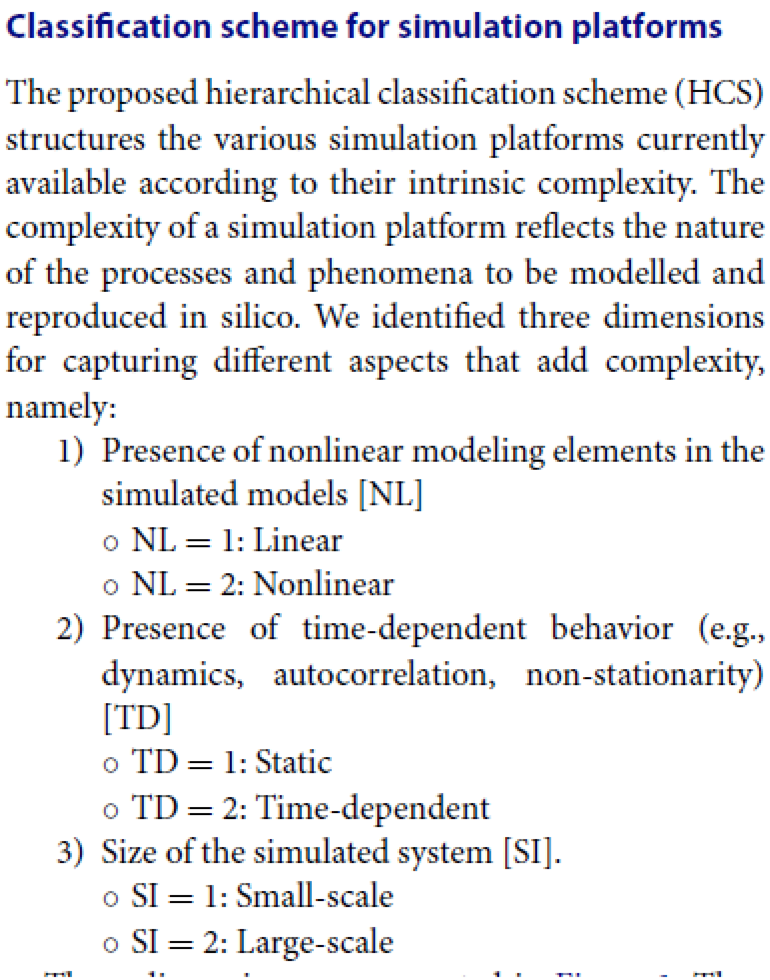
Taylor & Francis
Taylor & Francis Group

A structured overview on the use of computational simulators for teaching statistical methods

Marco Reis [a] and Ron S. Kenett [b,c,d]

Simulations generate data used in learning analytics

- A **hierarchical classification scheme (HCS)** for educational process simulators reflecting their inherent complexity.
- Describe training situations with integrated, comprehensive and coherent pedagogical solutions based on the use of simulators.



Classification scheme for simulation platforms

The proposed hierarchical classification scheme (HCS) structures the various simulation platforms currently available according to their intrinsic complexity. The complexity of a simulation platform reflects the nature of the processes and phenomena to be modelled and reproduced in silico. We identified three dimensions for capturing different aspects that add complexity, namely:

1) Presence of nonlinear modeling elements in the simulated models [NL]
   - ○ NL = 1: Linear
   - ○ NL = 2: Nonlinear
2) Presence of time-dependent behavior (e.g., dynamics, autocorrelation, non-stationarity) [TD]
   - ○ TD = 1: Static
   - ○ TD = 2: Time-dependent
3) Size of the simulated system [SI].
   - ○ SI = 1: Small-scale
   - ○ SI = 2: Large-scale

Hierarchical Classification Scheme (HCS)

Presence of non-linear modelling elements in the simulated models [NL]

NL=1: Linear

NL=2: Non-Linear

Presence of time-dependent behaviour (e.g., dynamics, autocorrelation, non-stationarity) [TD]

TD=1: Static

TD=2: Time-dependent

Size of the simulated system [SI]

SI=1: Small-scale

SI=2: Large-scale

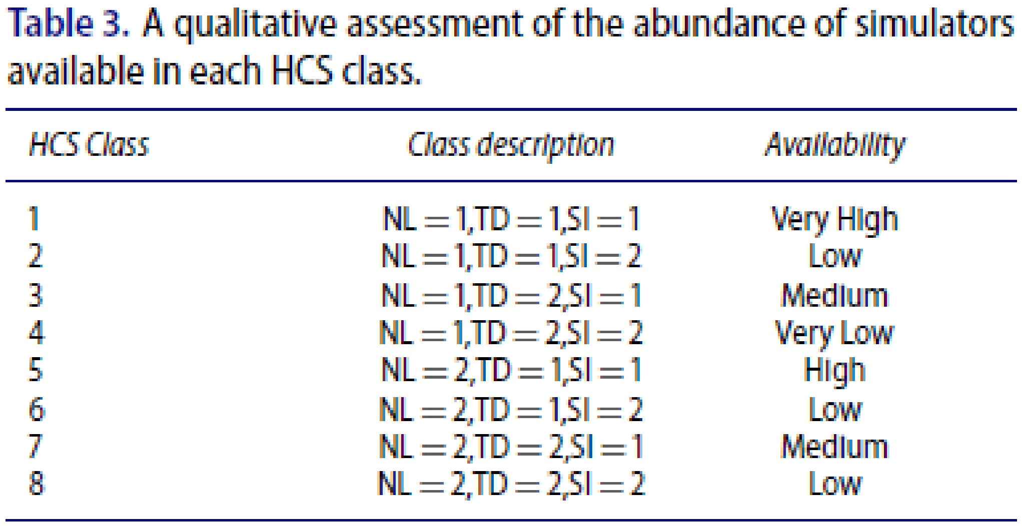
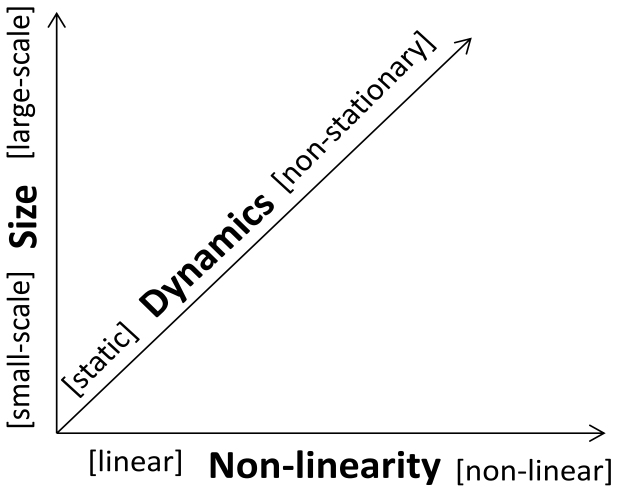
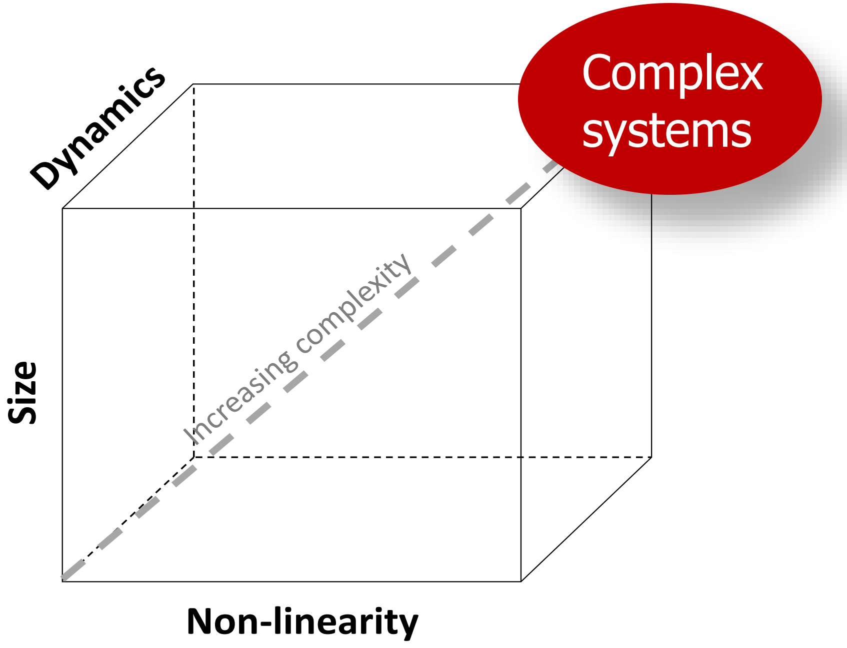


Table 3. A qualitative assessment of the abundance of simulators available in each HCS class.

HCS Class	*Class description*	*Availability*
1	NL = 1,TD = 1,SI = 1	Very High
2	NL = 1,TD = 1,SI = 2	Low
3	NL = 1,TD = 2,SI = 1	Medium
4	NL = 1,TD = 2,SI = 2	Very Low
5	NL = 2,TD = 1,SI = 1	High
6	NL = 2,TD = 1,SI = 2	Low
7	NL = 2,TD = 2,SI = 1	Medium
8	NL = 2,TD = 2,SI = 2	Low



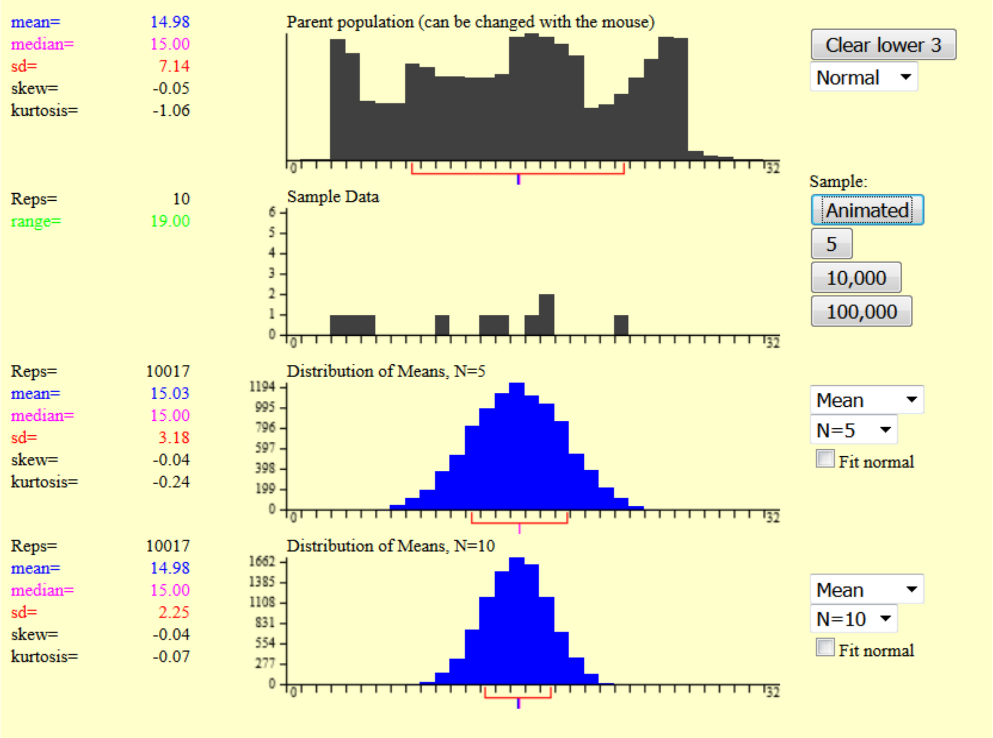


Complex systems

https://onlinestatbook.com/stat_sim/index.html

Class 1:
NL=1, TD=1, SI=1,

- Rice Virtual Lab in Statistics, *onlistatbook*
  - Many applets
  - E.g. Central Limit Theorem



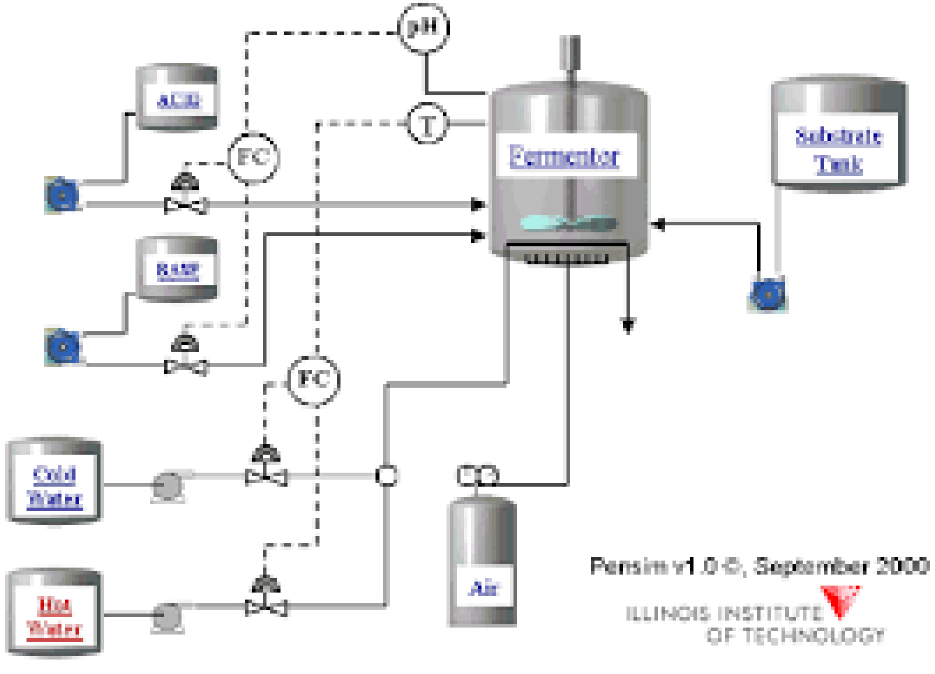
mean= 14.98
median= 15.00
sd= 7.14
skew= -0.05
kurtosis= -1.06

Reps= 10
range= 19.00

Reps= 10017
mean= 15.03
median= 15.00
sd= 3.18
skew= -0.04
kurtosis= -0.24

Reps= 10017
mean= 14.98
median= 15.00
sd= 2.25
skew= -0.04
kurtosis= -0.07

Class 8:
NL=2, TD=2, SI=2



PENSIM

http://www.industrialpenicillinsimulation.com/

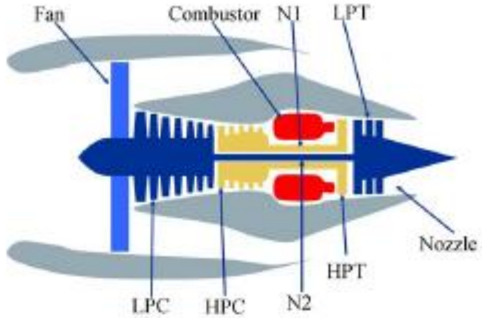


Figure 1. Simplified diagram of engine simulated in C-MAPSS [11].

https://ti.arc.nasa.gov/publications/154/download/

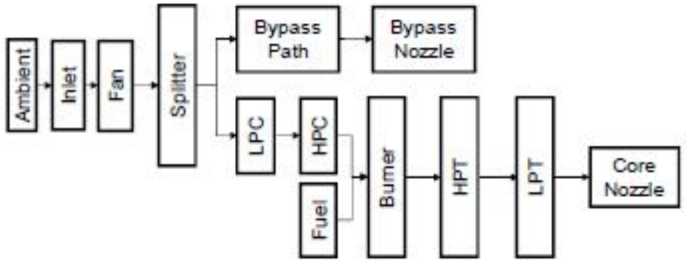
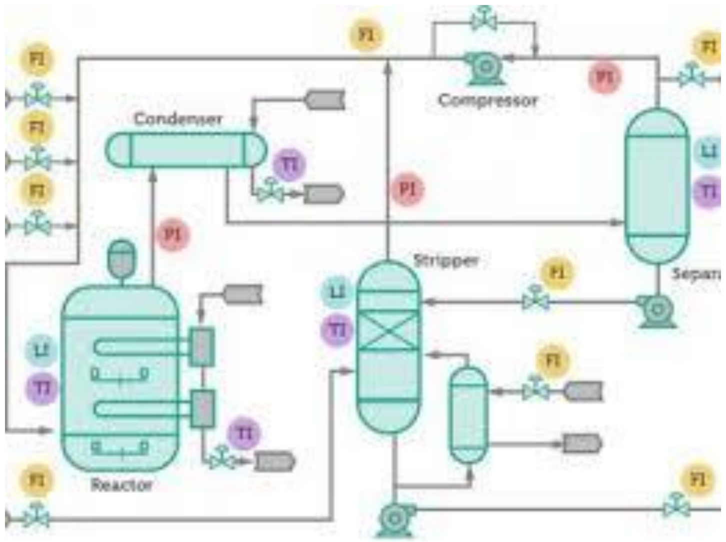


Figure 2. A layout showing various modules and their connections as modeled in the simulation [11].

https://depts.washington.edu/control/LARRY/TE/download.html



Tennessee Eastman simulator

Example of a Curriculum Roadmap with simulations

Modules	HCS Class	Examples of possible simulators
1-Basic Statistics	1	CAST (Textbooks for Learning Statistics - Public Cast E-Books), Rice Virtual Lab (Rice Virtual Lab in Statistics)
2-Multivariate Statistics	2,3,5,6	Latent variable models (Burnham, et al. 1999, Reis and Saraiva 2008), Statlab (Boon, et al. 2008), Aluminium Wheels (Greenfield Research)
3-Process Control (Basic)	1,3,4	Aluminium Wheels (Greenfield Research)
3-Process Control (Intermediate)	3	CSTR [Appendix], Distillation columns (Wood and Berry 1973), Heat-exchangers (Ingham, et al. 1994)
3-Process Control (Advanced)	2,3,4,7,8	Latent variable models (Burnham, et al. 1999, Reis and Saraiva 2006a, 2008, Rato and Reis 2011), CSTR [Appendix], Tennessee Eastman (Downs and Vogel 1993)
4-Design of Experiments (Classical)	5	Statlab (Boon, et al. 2008), env2exp (Env2exp)
4-Design of Experiments (Quality by Design)	5	Statlab (Boon, et al. 2008), Williams-Otto reacting system (Williams and Otto 1960)
4-Design of Experiments (Computer Experiments)	7,8	PENSIM (Birol, et al. 2001), Tennessee Eastman (Downs and Vogel 1993)

Level 1

- Introduction to Industry 4.0
- Introduction to IIoT and Connectivity
- Intro to Networking & Cyber Security
- Intro to Big Data for Industry 4.0

Level 2

- Advanced Industry 4.0 Concepts
- Advanced IIoT and Connectivity for Industry 4.0
- Advanced Cyber Security for Industry 4.0
- Intro to Industry 4.0 Software Technologies

Level 3

- Advanced Data Science for Industry 4.0
- Industry 4.0 - The Ecosystem
- Industry 4.0 for Business

- Intro to Networking & Cyber Security
- Intro to Big Data for Industry 4.0

The curriculum explores the modern world of data, including its collection, processing, management, visualization, and ultimately, its uses. The course also delves into big data implementation in cutting-edge manufacturing, and machine learning, predictive analytics, modeling, simulation, improvement of processes and progress indicators.

Course Outline

- Introduction to Big Data
- Characteristics of Big Data and Dimensions of Scalability
- Intelligent Decision Making and Getting Value Out of Big Data
- Data Collection and Management
- Algorithms, Computing, and Descriptive Statistics
- Data Analysis
- Visualization of Data
- Predictive Analytics and Modeling
- Machine Learning
- Introduction to KPIs
- Improving KPIs with Big Data
- Database Fundamentals
- Data Warehousing
- Data Mining
- Cloud Computing for Big Data
- Data-Driven Innovation

Analytics roadmap

Thank you for your attention