Science Learning Environments for the Future Schools: Scaffolding disciplinary engagement, co-construction and -regulation of disciplinary understanding through digital tools

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The emotional, social and cultural aspects of collective action:
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Unknown future from the view of education

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- learning, knowledge and skills in the future,
  - knowledge intensive work and knowledge demands increase strongly, and simultaneously
  - tasks that demand new, partly unforeseen knowledge and expertise increase, and are more and more often distributed
    - the knowledge needed does not yet exist; it must be created
    - disciplinary borders must be crossed; knowledge must be integrated
- possibilities or obstacles to attain this type of novel expertise are created from the beginning of learning trajectories

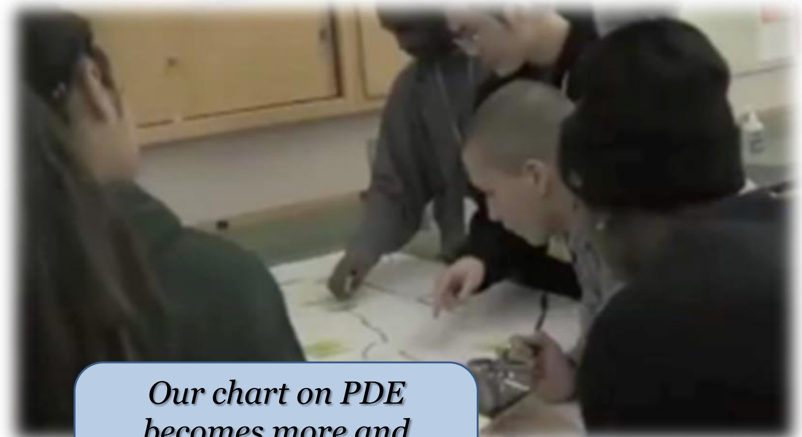
Challenges in science education and learning

- schools are expected to motivate a growing number of students into further studies in scientific fields, where they face increasingly new challenges and complexities
- above this, *all* students are expected to better understand core disciplinary ideas and the importance of scientific knowledge in dealing with e.g. big threats of our environment, which demands construction of coherent, deep understanding e.g. of eco-system, ocean acidification and climate change

  … not only as scientific issues but also as complex socio-scientific problems.

Challenges are not only cognitive

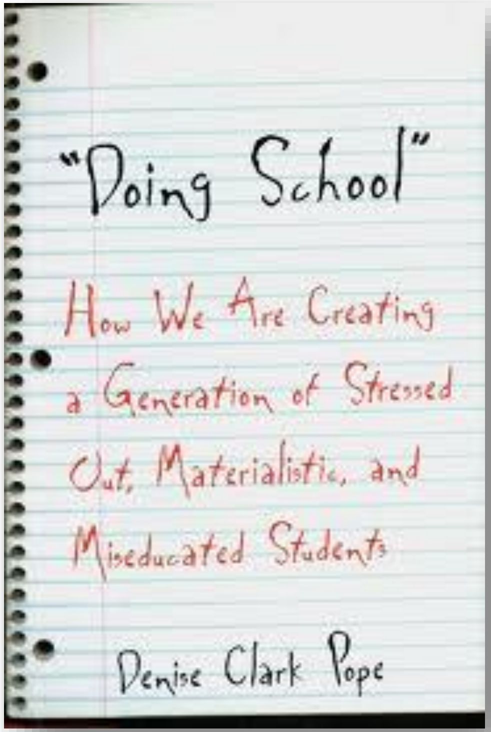
- When facing complexities, students are not only cognitively challenged but equally
  - motivationally (from performance ⇨ deep disciplinary engagement)
  - emotionally (coping with difficulty, complexity and high demands at the emotional level)
  - socially (tuning individual efforts and learning with socially regulated learning) challenged



Our chart on PDE becomes more and more complex... getting a bit too...

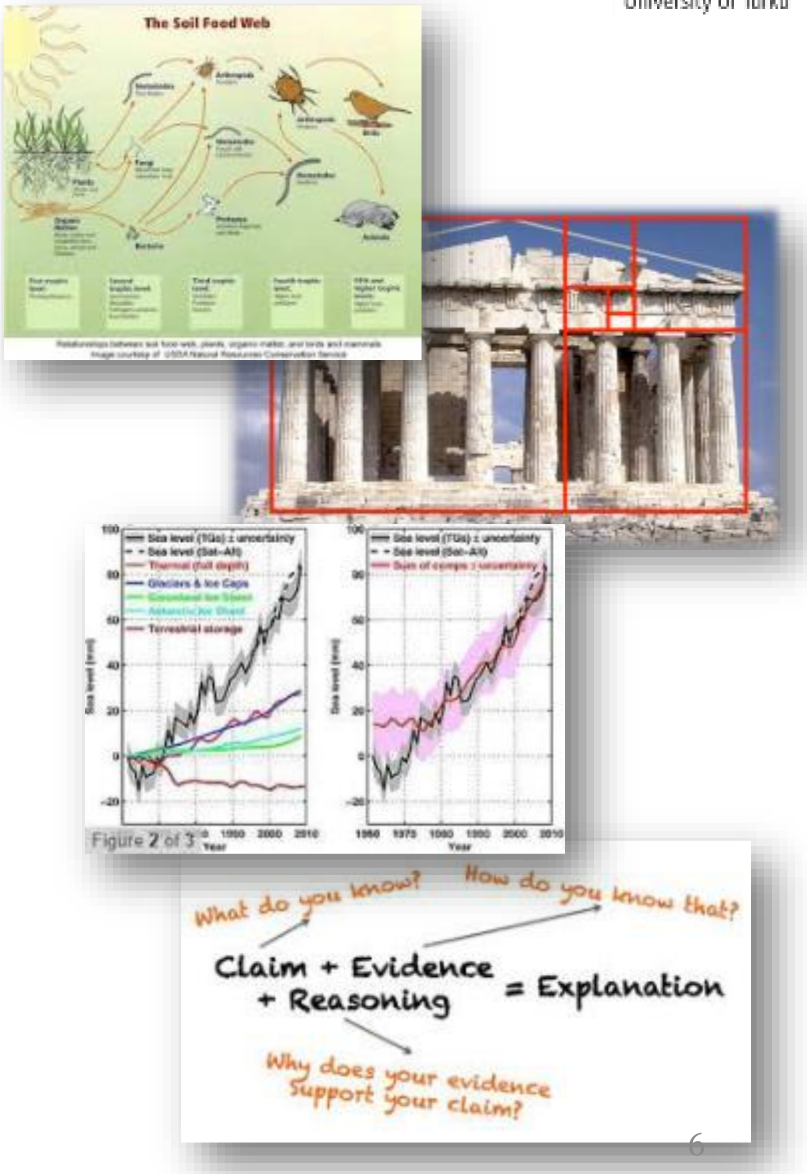
Challenging the traditional school world

- complex, realistic, and challenging science learning environments increase students' likelihood of using the skills learned during school activities in real-world applications
- because they are in school, however, students sometimes see these activities as primarily school tasks to be finished quickly
- the success of these complex learning environments in promoting better learning depends on understanding the processes of engaging students deeply in science practices



Digital tools as resources

- digital tools have opened new possibilities for learning and teaching, as examples
  - access to large data produced in real research
  - modelling complex processes
  - experiments and tests in virtual environment
  - ⇨ as resources to learn and teach, e.g.
    - scientific thinking and reasoning
    - critical literacy
    - knowing exceeding disciplinary borders
    - collaboration producing deep understanding and capacities for knowledge creation
- digital tools challenge the traditional school teaching (*Säljö, 2010*)



Designing an engaging virtual learning environmen

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- *Virtual Marine Scientist (VMS)* *(Fauville et al., 2013)*
- *Virtual Baltic Sea Explorer* (ViBSE) *(Telenius, Lehtinen, Kinnunen, Vauras et al., 2014)*
- ViBSE is built on a coherent pedagogical model and practices as well as key ideas and concepts of ***ecology*** of the Baltic Sea
  - focuses on the environmental problems of the Baltic Sea from the viewpoint of both chemistry and biology
  - all virtual experiments are founded on articles in marine biology journals and real research data
  - the experiments are carried out on an expedition in the virtual (but in reality existing) research vessel Aranda (owned by the Finnish Environment Institute SYKE)
  - although students learn in the context of the disciplines of biology and chemistry, the idea is to link experimental research and its outcomes to environmental policy issues to add both understanding of complex socio-scientific problems and personal involvement as a citizen

VMS was used in our pilot studies

Principal external ViBSE collaborators:

Mathias Scheinin, Åbo Akademi

Geraldine Fauville, University of Gothenburg

Milo Koretsky, Oregon State University

Sidenote on constructing learning environments

- learning environment offers room for (and teachers implement) instructional practices that boost students’ engagement based on principles of supporting student competence, autonomy, belongingness, and making learning meaningful *(e.g., Turner & Fulmer, 2013)*
- authentic tasks and activities strengthen disciplinary engagement, autonomy and responsibility in the journey towards flexible, adaptive and creative know-how

Engagement in learning

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- Our aim is to understand, what is and how to stimulate and support Productive Disciplinary Engagement (PDE) (*Engle & Conant, 2002; Engle, 2012; see also e.g., Nolen et al., 2012; Nolen, Vauras, Koretsky & Volet, 2014) <* more than mere engagement

- Disciplinary: learners use discourses & practices of the discipline (e.g., group is engaged in scientific thinking and activity vs. compliance or "doing school")
- Productive: "to get somewhere over time" (e.g., make progress toward a shared goal: produce a better plan, construct a better argument, develop a product)

- Thus, PDE can be defined as "a state when students are genuinely involved and attracted with gaining understanding, doing an action, using discipline-related language or reasoning that a professional or a knowledgeable citizen would do or use with the aim to accomplish a discipline-related task, e.g., solve the problem at hand or move toward a reasonable solution

Quest of PDE

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- capturing important socially shared learning related processes that (hypothetically) characterize PDE
  - co-construction of knowledge *(Volet, Summers, & Thurman, 2009)*
  - co-production *(Volet et al. 2009a; Khosa & Volet, 2014)*
  - socially shared metacognitive regulation (SSMR) *(Iiskala et al., 2004, 2011; Volet, Vauras & Salonen, 2009; Volet, Vauras, Khosa & Iiskala, 2013)*
  - cohesive (chemistry & biology) disciplinary argumentation *(Telenius et al., in prep.)*
- the role of emotions in cognitive engagement
- patterns of teacher scaffolding in collaborative learning *(e.g. Vauras, Kajamies, Kinnunen & Lehtinen, 2013)*

Main collaborators

Murdoch University

Simone Volet

Advancing future primary teachers' engagement in science inquiry learning

Australian Government
Australian Research Council

OSU Oregon State University

Milo Koretsky
Debra Gilbuena

University of Washington 1861

Susan Nolen
Gavin Thierney

Data from all four sites
- supporting PDE in complex, demanding STEM learning environments
- material or virtual tools
- face-to-face collaboration
- student teams take on professional disciplinary roles
- rich interaction data

Co-construction and co-production

- Co-construction and co-production are coded as high- or low-level *(Khosa & Volet, 2014; Volet et. al., 2013)*

Content-processing	Low level	High level
	reading verbatim, clarifying basic facts, describing, defining, questioning for details	elaborating, interpreting, inferencing, speculating, relating, questioning for understanding, meaning-making

Content-processing and SSMR were studied with veterinary medicine students, e.g. while constructing a concept map of a real clinical case (*Khosa & Volet, 2014*)

Cognitive engagement	
Task co-production	
Low level	Group effort to produce the task outcome without explicit conceptual justification
High level	Group effort to produce the task outcome with explicit conceptual justification
Knowledge co-construction	
Low level	Group effort to gather all the information [relevant to the clinical case]
High level	Group effort to enhance their conceptual understanding [of the clinical case]

Socially shared metacognitive regulation (SSMR)

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- the role of metacognition in learning is to monitor and regulate the learning process and disciplinary thinking towards a goal
- shared goals are crucial when students are engaged in high-level collaborative processes in which they co-construct meaningful knowledge and understanding *(Volet et al., 2009a)*
- special attention to socially shared metacognitive regulation (SSMR), which refers to the participants' goal-directed consensual, egalitarian and complementary monitoring and regulation of joint cognitive processes *(e.g., Vauras et al., 2003; Iiskala, Vauras, Lehtinen, & Salonen 2011; Volet et al., 2013)*
- the function of SSMR is to facilitate the building of a shared representation of the project and goals by the collaborative group
- another function of SSMR is to execute control processes, namely to inhibit inappropriate conceptualizations and to turn attention to others *(Iiskala et al. 2011)*
- SSMR is triggered e.g. by metacognitive experiences, often emotionally laden (like puzzlement, worry, excitement)
- both cognitive engagement and metacognitive regulation can be seen as integral processes for the group to move into and to retain at the state of PDE

Learning context (Finland) and processes

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[TUR2_V1.mp4](TUR2_V1.mp4)

Co-construction of knowledge

Socially shared metacognitive regulation SSMR

Possibility to teacher scaffolding

Co-production Completing a scientific experiment in the virtual laboratory (aim)

Virtual laboratory and information sources as support for thinking and learning

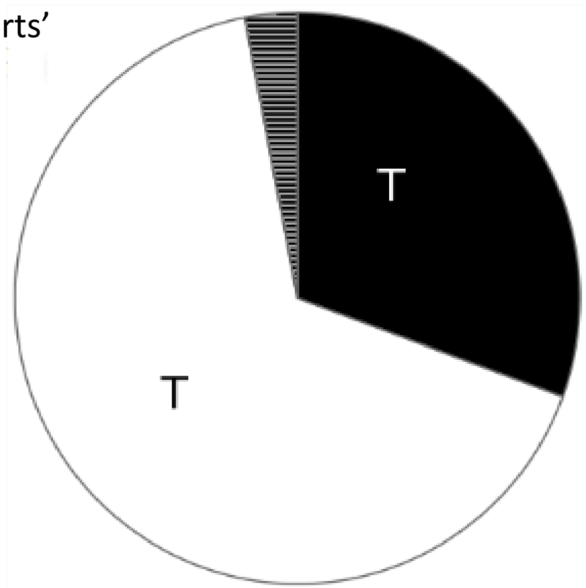
17-18-year-old students at upper secondary schools

SSMR in cognitive engagement *(Khosa & Volet, 2014; Volet et al., 2013)*

Level of the concept map : match to experts' map 56 %

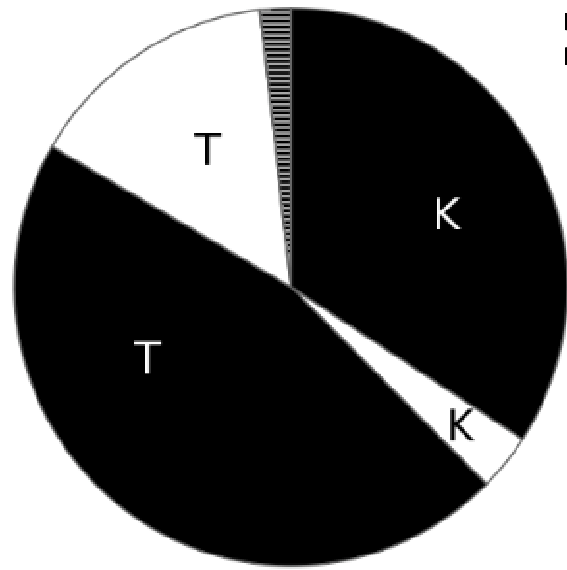
... but SSMR was associated with lower level cognitive engagement and only to co-production

Group MUR1



21 % reflected metacognitive regulation, of which 60 % was socially shared (SSMR)

Group MUR2



Level of the concept map : match to experts' map 92 %

... but SSMR was associated to higher level cognitive engagement and both to co-construction and co-production

21 % reflected metacognitive regulation, of which 69 % was socially shared (SSMR)

T = Co-production	■ High-level
K = Co-construction	□ Low-level

Some concluding remarks

- Preliminary assessment of our students collaborating in the virtual laboratory indicates rather similar differences between the groups as in the Australian data with veterinary medicine students
- SSMR in itself do not help us to understand deep productive disciplinary engagement and learning outcomes, but we need to relate SSMR to the quality of ongoing shared cognitive processes
    - task performance (”doing school”; *Nolen et al., 2014)* vs. combining disciplinary thinking and meaning-making to high-level production
- as important as it is to understand what triggers regulatory acts, perhaps even more important would be to understand what inhibits regulation to take place in collaborating teams

“Sometimes thinking inside the box is very comforting”
Rosie 5 years

Thank you for your attention!

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