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## MUPEMURE - Multiple Perspectives on Multiple Representations

Armin Weinberger, Daniel Bodemer, Manu Kapur, Gaëlle Molinari, Nikol Rummel

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# MUPEMURE – Multiple Perspectives on Multiple Representations

White Paper

## 1. Introduction and Motivation

Our understanding of STEM (science, technology, engineering, and mathematics) topics such as statistics, photosynthesis, the water cycle, etc. is strongly evoked and guided by how these topics are graphically or textually represented in text books or online environments. Sharing multiple perspectives on multiple representations (MUPEMURE) can affect the course and type of learners' reasoning by disambiguating discourse, fostering self-explanation and elaboration, and by strengthening a shared task focus. Latest educational technology for creating, modifying, and sharing representations in TEL (Technology-Enhanced Learning) scenarios needs to be combined with dedicated instructional approaches such as group awareness and scripting approaches as well as artificial intelligence to investigate the following research questions:

- How can we conceptualize knowledge being distributed in multiple (external and internal) presentations and agents across technology-enhanced learning landscapes?
- How do learners coordinate multiple representations and converge (or diverge) upon shared, canonical representations?
- How can learners be facilitated to actively share, process, and acquire multiple perspectives on multiple representations of STEM topics in TEL environments?

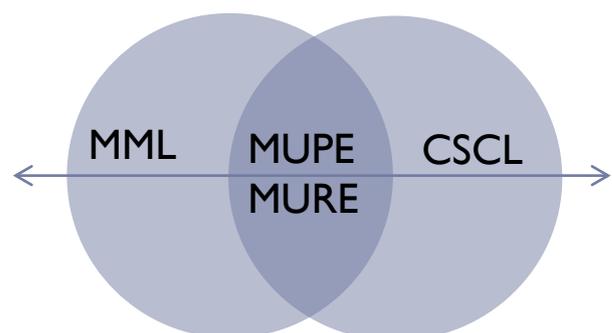
A large body of research has been concerned with learners' difficulties to detect and avoid

misconceptions and to construct relations between multiple representations for building coherent mental representations of STEM topics. Moreover, much research has been invested in the questions of how to choose the optimal representation of knowledge to optimize cognitive load and how to design multiple representations for learning purposes. MUPEMURE builds on this work and takes it further by asking how learners can be facilitated to actively create and modify multiple representations and acquire multiple perspectives on science topics through specific, collaborative knowledge building activities.

This new perspective on representations is addressing current online scenarios of knowledge construction, e.g., in social networking sites, where learners can create, upload, and discuss pictures and videos.

With the 1<sup>st</sup> MUPEMURE workshop at the Alpine Rendez-Vous in La Clusaz, 2011, we aimed to bring together the scientific communities of Multimedia Learning (MML) Research and research on Computer-Supported Collaborative Learning (CSCL) and identify the overlap of these research fields in which MUPEMURE research can be allocated (see Fig. 1).

Fig. 1. MUPEMURE in the overlap of MML and CSCL research



To do so we have invited two renowned experts in the field of Multimedia Research who have dealt with the collaborative use of representations before, Shaaron Ainsworth and Mireille Bétrancourt for key talks. Moreover, we have funded PhD students to position themselves with respect to MUPEMURE, present their emerging work, and create new MUPEMURE research ideas.

## 2. Workshop Description

The workshop covered a number of activities involving keynotes, representing and categorizing the research of the participants as well as breakout groups to better identify and address the emerging field of MUPEMURE (see Tab. 1).

Tab. 1. The MUPEMURE workshop program

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March 30

08.30 Welcome

08.45 Representing research (graphically):  
Individual sketches of own research

09.45 Presenting research: Fire hose presentations  
of participants' projects (max. 5 min. each)

11.45 Categorizing research: Positioning and  
discussion of the contributions

12.15 React

16.30 Key note: Shaaron Ainsworth Understanding  
Multi-representational Learning: Where are we,  
where do we want to be and how should we get  
there?

17.30 Creating research: Break-out groups for  
converging on joint MUPEMURE studies

19.30 Discussing research: Plenary session

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March 31

08.30 Key note: Mireille Bétrancourt When  
collaboration fosters learning with animated and  
static graphics... and conversely

09.30 Towards a MUPEMURE model: Thematic  
clusters

10:45 Identifying emerging issues in the field of  
MUPEMURE: Plenary discussion

11.30 Résumé

12.15 React

13.30 Outlook: MUPEMURE practitioner  
workshop and symposium at CSCL 2011; and  
potential future activities

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## Keynotes

Two keynotes have been given; one by Shaaron Ainsworth titled "Understanding Multi-Representational Learning: Where are we? Where do we want to be? How should we get there?" and one by Mireille Bétrancourt titled "When collaboration fosters learning with animated and static graphics ... and conversely".

Shaaron Ainsworth' talk laid some foundation on where research on multiple representations is at and discussed what is over- and what is under-investigated in this field. The research on multiple representations has under-emphasized how its results are supposed to impact the classroom and over-emphasized how representations should be designed. Future research should rather focus on how to support learners in making meaning from and translating between multiple representations as well as to encourage learners to create and construct their own representations.

Mireille Bétrancourt's keynote similarly discussed how research on designing the most appropriate representations is limited and demonstrated a study on how representations are being comprehended in a collaborative learning arrangement. Her research indicates that collaborative learning with multiple representations can be starting point for harvesting the full potential of multiple representations as well as collaboration for learning when learners use some additional support tailored to collaborative learning arrangements, e.g., recapitulative snapshots, and tools, e.g., providing learners with full control over playing and pausing an animation.

## Participants' research

Introducing a series of fire hose presentations, members of the *JTEL winter school* indicated among other things how augmented reality is a new paradigm emerging in Technology-Enhanced Learning and how research on multiple representations needed to be applied in it.

*Krista DeLeeuw* investigated the underlying cognitive processes of individual and collaborative learning with multiple external representations. Her research indicates that collaborative learners process representations more actively than individual learners.

*Daniel Bodemer* next presented a complex CSCL environment in which learners needed to translate between and actively integrate multiple given representations and were made aware about the state of integration of the learning partners, which lead to better individual learning gains.

*Julia Eberle and Gerhard Fischer* introduced the concept of meta-design for formal and informal learning, i.e. allowing participants in run-time to change the design of an environment for creating multiple (truly unforeseeable) representations. The evolving multi-representation scenarios fundamentally differ in respect of the type of community (community of interest versus community of practice), the boundary objects, and the internal and external scripts involved supporting reflection in or reflection on action.

*Anniken Furberg, Anders Kluge, and Sten Ludvigsen* investigated how groups are sharing representations and how this is connected to a trajectory of interactions and developing representations. They found that students first reconstruct the information given by teachers and then create hypotheses in a computer-supported inquiry environment.

*Hannie Gijlers, Alieke van Dijk and Armin Weinberger* presented studies of tablet-supported collaborative drawing in elementary school combining collaboration scripts and awareness tools to highlight and guide learners to resolve cognitive divergences. Their results show that those instructional approaches substantially facilitated processes and outcomes of learning about science phenomena.

*Manu Kapur* introduced his concept of productive failure: Opportunities of students to “mess around” with the task are pivotal to arriving at more systematic views and approaches.

*Anders Kluge and Ingeborg Krange* presented the MIRACLE project (Mixed Reality Interactions across Contexts of Learning). Bridging virtual and real spaces as well as school, the web, and the museum, learners can manipulate interactive models concerning energy production and consumption.

*Natasa Lackovic* laid out how she uses pictorial representations of abstract concepts to shape real

classroom discussion. She aims to investigate the relation between multiple representations and different types of discussion these representations mediate.

*Inge Molenaar* investigated pedagogical agents facilitating meta-cognition. Her results indicate that the interaction between the group members amplifies the effect of scaffolds, especially those in form of questions.

*Gaëlle Molinari* demonstrated how peers mutually model each other’s knowledge with concept maps in CSCL. She orchestrated individual and collaborative learning phases and varied similar and complementary knowledge resources to facilitate transactivity, i.e. the extent to which learners operate on each other’s reasoning.

*Jochen Rick* presented his work with tabletops for learning mathematics, DigiTile, with which elementary students can link multiple representations of mathematics. This work shows how learners can benefit from directly manipulation multiple representations.

*Sascha Schanze* showed with his work “what words cannot express”, how self-constructed representations, e.g., drawings, concept maps, work sheets, in CSCL for the chemistry class can promote progressive reflection. Schanze stresses the potential of self-constructed representations for revision through peer interaction. Drawings seem to partly meet learners’ problems to translate between different representations.

*Mike Tissenbaum, Michelle Lui, and Jim Slotta* investigated how learners construct personally meaningful artifacts with computer support inside and outside the classroom. Their notion of the smart classroom allows teachers to understand and alter the flow of class activities with computer-supported scripts.

*Dimitra Tsovaltzi* investigated how externalization of (erroneous) internal representations in CSCL could be facilitated with error-awareness prompts, to foster construction of canonical knowledge in turn.

*Katharina Westermann and Nikol Rummel* follow up on Kapur’s productive failure work and complement it with some guidance in form of

motivational prompts (e.g. "keep going") or cognitive prompts (e.g. "maybe your solution does not always work, here you have a counterexample"). Small groups of learners use Tablet-PCs to construct multiple representations such as tables, graphs, and formulas to foster mathematical literacy.

### Breakout groups

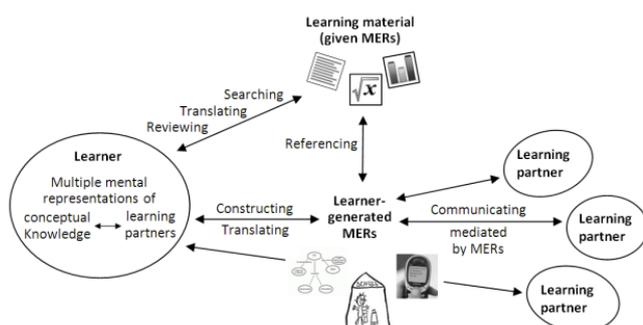
To further integrate the various studies placed within MUPEMURE, groups were formed that consisted of participants covering different areas of the field of MUPEMURE, i.e. approaching MUPEMURE rather from a MML or rather from a CSCL research perspective (see Fig. 1). All participants positioned themselves and each other on this schematic representation of MML-MUPEMURE-CSCL research and heterogeneous dyads were identified ahead of the workshop.

These dyads focused on enhancing transfer with and across multiple representations (Anniken & Katharina), supporting sharing whilst creating solutions in formal and informal learning (Anders & Mike), bringing communities of multiple disciplines together with boundary objects (Gerhard, Julia, & Natasa), how to manipulate representations to support learning (Inge & Jochen), what representations to choose and how to sequence them (Krista and Sascha), how to foster representational competency (Gaëlle, Mireille, & Shaaron), and how to build on heterogeneities in the classroom and supporting learners working with erroneous examples at the right time (Dimitra & Hannie).

### Towards a MUPEMURE model

One central goal of the workshop was to advance a model of MUPEMURE.

Fig. 2. Model of MUPEMURE.



Starting from a representation highlighting given and self-constructed representations being produced and processed by the individual as well as shared among peers (Fig. 2), missing dimensions were identified, such as computers and tools for representing something, learners' prerequisites (e.g. representational competencies) or the teacher's role in the way multiple representations are selected and/or in the orchestration of learning activities with multiple representations.

In two larger breakout groups as well as in the plenum, the MUPEMURE model was discussed:

Bringing MML and CSCL together addresses how a group can coordinate itself by external representations taking into account the particular characteristics and capabilities of CSCL. External representations then are needed to externalize and eventually converge on a shared understanding. In this regard, CSCL is fundamentally building on and being scaffolded by various external representations. Externalizing representations that can be interpreted by computers can then create situations, in which computers can be programmed to provide some basic responses and advanced tools dealing with learners' representations.

Moreover, representations and collaboration may have some reciprocal effects. Specific representations may foster specific interactions and vice versa, some forms of collaboration may lend themselves to specific external representations.

Representations can have a strong influence of learners' understanding, especially when they are regarded as being correct and representing canonical knowledge. In CSCL research, the notion of productive failure emerged showing that non-canonical representations may pose far greater learning opportunities under specific circumstances than representations, which are known to be correct. Being able to trace the development of representations may therefore be a smart way to tweak learners' understanding and epistemological beliefs.

### 3. Emerging Research Questions

In addition to our motivating questions (see p. 2), the following questions emerged in the plenary discussions on advancing the MUPEMURE model:

How can the temporal dimension of phenomena be represented?

In this respect, snapshots, narrations, video etc. can help and needed to be carefully combined to arrive at a good fit between representing a whole process and being data-economical.

How do we represent collaboration?

Do we start from the individual learners to the group arguments (from MML to CSCL): → external representation → triggers an internal representation → shared and combined between learners that may lead to higher levels.

or

from the group to individual learners' arguments (from CSCL to MML): → representing individual learners' → knowledge construction in the collaborative moment → does not reside in the individual head → it is an ontological problem with where knowledge resides → but the knowledge creation that happens in the collaboration.

Starting with the MML hypotheses (see e.g. Schnotz), (H1) external representations → facilitate the construction of more elaborate internal representations → improve the quality of collaboration → results in higher levels of learning outcomes OR (H2) different external representations → lead to different internal representations → result in different patterns of collaboration and learning outcomes.

If we start with the CSCL hypothesis: external representations → facilitate the visualization of differences and also potential gaps between learners' knowledge → improve collective cognitive convergence → may result in higher levels of learning outcomes.

Which process drives the other, is collaboration driving representations or do representations drive collaboration?

Two parts of the cycle → chicken egg problem → collaboration ⇔ representation → where do you come from → What do you want to foreground? The researcher should make the decision depending on his/her background.

Summing up, starting at the social or at the individual level is an ontological debate; the position of technology depends on its function; the driver to connect CSCL and MER is the construct of externalization; which construct is leading depends on our position as a researcher and our research question.

### 4. Grand Challenge Problems

Many technical novelties allow for new cultural practices of dealing with knowledge and representations. Learners are frequently online with mobile devices; they share their reality with friends taking and uploading photos and videos into social networks wherever they go. New (mobile) hardware with multi-touch surfaces, such as iPads or tabletops, allow for the direct manipulation of representations. One of the fundamental challenges for society and education will be to foster an active, smart and responsible use of these knowledge-at-your-fingertips-devices rather than a media consuming only attitude. The learning opportunities have drastically increased. Learners may use formal and informal learning opportunities online, e.g., learn by free lessons shared on YouTube, and be confronted with views and representations diverging from their face-to-face education. Formerly individual learning scenarios, like reading a book, may become a collaborative experience with the use of eBooks. To exploit the benefits and reduce the barriers peer learning entails, instructional approaches need to be translated and created anew for TEL scenarios, such as scripting collaboration or making learners aware. To benefit from MUPEMURE, it may be pivotal to design for smart ways of data reduction to foster comprehension, i.e. to avoid "data obesity". This means to be intrusive at the right time right person in the right way.

The following Grand Challenge Problems have been posed and elaborated by the Provocateur of the workshop, Nicolas Balacheff:

A semiotic recommender system to decide which representation can fit learning needs at best

Technology offers a large range of possibilities to represent learning objects and content, either in texts, hypertexts, drawings, animations and films. All these representations present advantages and limits which are rarely presented precisely to teachers who have to choose material for their teaching next day. This choice is very complex because of the large number of aspects to take into account: nature of the content to be taught, variety of the available resources (computers, digital tablets, smartphones, phones, pocket calculators, paper & pencil), constraints on the communication (on site, at a distance, with or without shared visualizations), learners' competence and needs. A great scenario would be for the teacher to describe the content and the constraints, and then get advice about the representations which would fit at best the learning needs. Further development would be to express these needs and get the resources which on the net fit at best the requirements.

What problems of the European education system are addressed, and what are the long term benefits for society?

This GCP is not specific to European education systems, it is of an international relevance. Then, the problem is related to the "data deluge" and the difficulty of finding the proper resources within the Internet. The long term benefit is the enhancement of the professional activity of the teachers and a more efficient exploitation of the learning potential of the internet. With learners able to express their needs, one may expect such a system to provide responses to a question by selecting the most adapted representation. This technology may not only impact learning but also the use of the internet within an informal learning context.

What are the main activities to address this Grand Challenge Problem?

From the scientific perspective this challenge calls for a high level collaboration of computer scientists, with researchers having a specific expertise in semantic, learning science, semiotic and epistemology. The main activity should be a project (STREPS type) with a consortium gathering

the said competence and as a key production a prototype of such a tool in a well-defined and not too complex domain (esp. a domain in which the issue of representation is not completely open from the learning science and semiotic perspective).

Additionally, related research projects could be designed to explore the following complementary features:

- Indicators to recognize the right moment/time to provide non-intrusive feedback/scaffolding to learners
- Indicators on when, how, and what kind structuring the learning process should be provided in a personalized way;
- Criteria for choosing the effective order of representation type (self-constructed created vs. pre-constructed given) depending on the expected processing and conceptual understanding of the learner

What is the timeframe for the Grand Challenge Problem?

A 3-years STREP

What are measurable progress and success indicators?

To be able to run a demonstrator in a non-trivial knowledge domain would be a good indication of success, together with an acceptable argumentation on its potential generality.

How can funding be attracted?

This idea could attract funding from the knowledge industry and Ministries of Education of EU member states. Such a problem can be the origin of successful European projects (STREP size).

When the representation is not there, how to introduce it and facilitate its adoption?

One of the challenges of teaching is to find a way to meaningfully introduce new representations when the hypothesis is that learners do not have this representation or any premises. This challenge is common to all disciplines in various forms, but it is of a special importance in the case of science where representations are more often than not

rigorously codified in semiotic registers and are used for computational purposes. A badly introduced representation can be the source of misconceptions, and also of exclusion of learners from the learning community since adopting a representation is not only a cognitive but also a social process.

Hence the problem of the introduction must be rooted in a two dimensional space: epistemological – understanding the role of the representation in the building and the use of a piece of knowledge – and sociological – understanding the communication dimension of the representation and its contribution to the construction of a community. Situations of communication associated to problem-solving situations are likely to provide the best context to facilitate the emergence, the sharing and the use of representations. This designates CSCL as the TEL research area in which tools and models could be found to take up this challenge.

This grand challenge problem is tightly related to the connecting learner and contextualizing learning Stellar Grand Challenges.

What problems of the European education system are addressed, and what are the long term benefits for society?

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This GCP problem is not specific to European education systems, it is of an international relevance. It raises many issues, among which the following which are of interest for formal and informal education:

- For a given piece of knowledge, what would be the communication and problem-solving characteristics of a situation allowing the emergence of a relevant and efficient shared representation?
- In the case of formal education, what are the constraints so that the emergent representation is either compliant to the one socially shared, or stands at a distance which allows the teacher to bridge the gap without “forcing” learners?
- In the case of informal learning, which hints would help to construct representations through processes allowing to manage the tensions between the variety of the individual needs and backgrounds and the construction

of the community sharing meaning and knowledge.

What are the main activities to address this Grand Challenge Problem?

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From a scientific perspective this challenge calls for a high level input from semiology and epistemology in tight relationship with educational research and engineering. It requires from computer scientists a better understanding of the interaction between knowledge representation, interface and their actual implementation. HCI requires epistemological characteristics, either reified or emergent, of the interface and its system of interactions to be revisited to produce models taking into account the “meaning” dimension and not only the functional dimension in computational terms (“meaning beyond affordance” may be the slogan).

The main activity should be a project (STREPS type) with a consortium gathering the said competence and a network of classroom or on-the-field learning communities to implement and evaluate the specifications of the situations. The content domain must be well-defined and not too complex (esp. a domain in which the issue of representation is not completely open from the learning science and semiotic perspective).

What is the timeframe for the Grand Challenge Problem?

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This GCP can be associated to long term basic research on meaning, learning and representation, and shorter term research project directly related to the current technology searching for its enhancement possibly targeting first domain specific research projects where educational problems are well identified.

A 3-years STREP would set a standard timeframe for the building of a first demonstrator.

What are measurable progress and success indicators?

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The explicit and precise description of the scenario for a successful learning situation fulfilling the mentioned properties and a consensus of the research community would be a first evidence of success. Then, an indicator would be the level of dissemination and the activity of a community of

teachers adopting these scenarios and engaging in discussions to understand and revise-improve them. Eventually, the adoption of the specification of scenarios to enhance CSCL environment making use of content specific representations will be a relevant criterion.

How can funding be attracted?

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A progress on this issue will have an impact beyond education, on the design of advanced HCI principle of design for environments which will provide services but also evolve with the user understanding of its functioning and its functionalities. This may be of interest for the knowledge industry and fit well in the EC agenda.

How can T(EL) support navigation across media and communities?

Navigating across text-based material is now a familiar practice on the Internet supported either by metadata retrieving or full text explorations of the documents. Even, some techniques (e.g. LSA) allow an exploration beyond the identification of common words, deriving commonalities in content from the recognition of lexical context (e.g. “I drove to Munich”, is conjectured to have a close semantic relation to “I took my car to Munich” thanks to a statistical knowledge of the co-occurrence of “driving” and “car” in texts). The last decade has developed the possibility to navigate among multimedia material; the complexity of the technology is of another order, because if it is a common idea that a picture is best than a thousand words, when one come to formalize the semantic of images or video, it appears to be much more complicated than for texts. Though, it happens that in learning contexts graphical representations and images are considered as extremely important tools to facilitate sense making or communicating knowledge. This is actually the core reason why working on multiple representations is so important, even critical for the development of efficient learning, teaching and training strategies. Then, a TEL research challenge is to provide the technology and understand the practices which will allow navigating among these representations taking into account learning requirements

What problems of the European education system are addressed, and what are the long term benefits for society?

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This GCP problem is not specific to European education systems, it as of an international relevance.

The navigation trail among the representations provides access to a learner representation profile (e.g. better learning curve with certain representations) and to clusters of learners sharing preferences (type of representation, type of treatments). Profile and clusters can be used to optimize group making in the design of CSCL scripts, or networking learners and teachers in a more efficient way so as to facilitate learning. A prerequisite is to specify a learning grammar for each type of representation.

What are the main activities to address this Grand Challenge Problem?

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This complex GCP might benefit from a series of seed projects on issues like: identifying the semantic proximity of representations of different types for a given content; identifying the productive differences between representations so that building on them can facilitate meaning making; defining a “measure” of the epistemic complexity of a representation; defining a “measure” of the cognitive complexity of a representation; specifying inter-representations manipulation in support of learning. This could last a period of 2 years, then be followed by a 3-years STREP-like project to integrate these results and propose a navigation toolkit to be used in other applications.

What is the timeframe for the Grand Challenge Problem?

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This is a mid-term research problem.

What are measurable progress and success indicators?

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Production of quantitative indicators of distance and likeliness of representations, benchmarking of these on a shared bank of learning representations, level of adoption of the toolkit by other projects.

How can funding be attracted?

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Representation grammars will provide a ground for tools necessary to navigate efficiently and

relevantly the Internet in search of resources. Including tangible representations (objects), this challenge will be in line with the foreseen web3.0 and hence of interest beyond the TEL research area. It can attract interest from researchers in semiology, computer-science, education and providers of Internet services.

## 5. Researchers and Communities

The communities involved in MML and CSCL research mainly consist of education and psychology researchers, but clearly also move beyond those disciplines. The concept of the Learning Sciences is indeed multi- and interdisciplinary. Some disciplines have been mentioned above; obviously, some more disciplines need to be involved:

Education is needed to design instruction, such as CSCL scripts or awareness tools, and to develop measurements of relevant processes and outcomes. Psychologists are needed to build this research on existing, sound methods and theories of cognition and motivation. Computer scientists are needed to co-develop new tools to create and share representations. Designers and artists are needed to contribute an understanding of aesthetics and historical backgrounds of representations.