Holistic Design of Visual Collaboration Arenas and Intelligent Workspaces

Abstract: Future industrial and societal computing solutions must be designed for sustainable operations to support evolutionary needs and opportunities, and realizing breakthrough Holistic Design methods.
To exploit the full potential of digitalization and smart devices we must apply them to practical cases, designing and enhancing workspaces and collaboration spaces, creating evolutionary action- and work-sensitive contexts. Intelligent workspaces will complement, enhance and at times replace natural language specifications, coded systems and information flows. Design of symbolic languages, visual knowledge models, and evolving capabilities, enabled and configured by active knowledge architectures, will revolutionize industrial computing and collaboration.
The MADONE partners have performed industrial and public pilot projects verifying that sector adaptable platforms give actors agile approaches and evolving collaboration capabilities and services. Evolutionary workplaces and collaboration spaces resolve digital challenges and open new opportunities, supporting flexibility, adaptability, reusability, traceability, predictability and sustainability. New business opportunities, scientific knowledge, citizen services and values, and innovation and learning will be designed and delivered.
Holistic design of oil and gas projects and operations is the industry case demonstrator described. Collaborative knowledge models enable design of new agile approaches to growing needs and challenges, exploring novel intelligent workspaces and digital technologies.

Keywords: *Holistic Design , Visual Collaboration Arenas, Knowledge Spaces, Intelligent Workspaces, Agile Approaches, Sustainable Solutions, and Practise-driven Innovation.*

1 Introduction

How to design, build and operate projects with agile workplaces and evolutionary networked collaboration spaces is further researched to enable user-friendly innovative solutions. Visual enterprise arenas supporting continuous innovation and learning must be created by all actors involved, smart machines and humans. The visual arenas must be based on a common knowledge base and foundation of configurable platform components. Knowledge and data models and powerful collaboration and viewing capabilities must be owned by roles with tools supporting their tasks and services.

Holistic design of visual collaboration arenas will enable value-chain collaboration, safe decision-making, traceable evolution and reuse and re-design of components.

Predictability, knowledge sharing, competence transfer, and management and reuse of intelligent workspaces and rich-context content is also enabled.

Future enterprise systems and evolving Visual Collaboration Arenas (VCAs) will be composed of these components: computing hardware, software, smart digital devices and robots, and Active Knowledge Models (AKMs). Categories of AKMs support cyclic design and execution of VCAs, evolutionary platforms and intelligent workspaces, and enable autonomous data, knowledge and work management.

The impacts on current societies, industries and practices will be heavy. The Active Knowledge Modelling (AKM) technology [4,7] is a disruptive approach, and existing ICT business, research and education will be transformed. Collaboration across teams of users, scientists, designers, suppliers, operators and digital actors implies that they will own and manage their workspace data and responsible tasks, discipline parameters and design and engineering rules. The workspaces of roles are context-rich working and living environments that must be holistically designed. The resulting methods, knowledge products and values are validated and commercialized in project demonstrators, see section 4. Industrial pilot projects must be established to drive commercialization. Holistic design of both industrial and public projects will cut times and costs by factors, and enable reuse of knowledge, methods, and solutions.

1.1 Current Practices

Business, project and solution developers, architects and users are today supported by domain-specific layered approaches and paper-based methods and disjoint work environments. Each business layer is divided in discipline-dominated stages connected by gateways, and supported by linked application systems. Instant collaboration, dynamic viewing, knowledge sharing and reuse, and competence transfer among stakeholders, users and suppliers is limited, if not altogether prohibited. Agile approaches to enterprise and project design, responding to growing variety, emergence and complexity of markets, regions and companies are being researched, but holistic design of reusable architecture-driven solutions are so far ignored. System design methods, knowledge management, innovation and learning have been research topics since 2005, but few operational results applying modern technologies are implemented. There are still too many political and commercial barriers preventing collaboration and new styles of computing, transforming coded applications and workplaces to dynamic model-based components and visual work environments**.**

Most industries and public sectors are involved in innovation projects developing Cyber-Physical Systems (CPS) [10]. CPSs are a result of last decade progress in embedded computing, networking, and nanotechnologies. CPS are characterized by a strong integration of devices and physical processes, device miniaturization, dramatic increase in the computational power of devices, lower demand for energy supply, sensing of the environment, new actuation possibilities, as well as ubiquitous communication. They present a new level of integrated intelligence that is characterized by interaction and coordination of computing processes with physical processes [1,11], as well as intensive human machine interactions in human-centered application sectors.

2 Design and Innovation of Visual Collaboration Arenas

Dynamic CPS design and operation will enable new applications in numerous public domains, like eHealth, where new solutions will enhance healthcare practices and services. Dynamic CPS design will also have beneficial impacts in industrial domains, such as Factories of the Future (FoF), where business models may be influenced by data from the sensing devices of a CPS. However, in most sectors there are life-cycle challenges and needs, such as innovating new approaches and practical methods for design and operation of new products and processes. This practice-driven innovation and learning and cyclic design and execution is not supported by existing CPS systems.

2.1 Implementing Visual Collaboration Arenas

A Visual Collaboration Arena (VCA) supported by a project platform is built by teams:

- A user-team composed of users, engineering and supplier experts, and use-case experts is responsible for customer solutions, capabilities and values.
- A knowledge modelling team composed of people with competence in holistic design methods and principles, and in building knowledge products, Active Knowledge Models (AKMs) and Active Knowledge Architectures (AKAs).
- An Evolutionary Project Platform (EPP) team with competence in using the core EPP &VCP tools, reusing knowledge products, and extending the contents, methods and capabilities, managed in the Project Knowledge Repository.

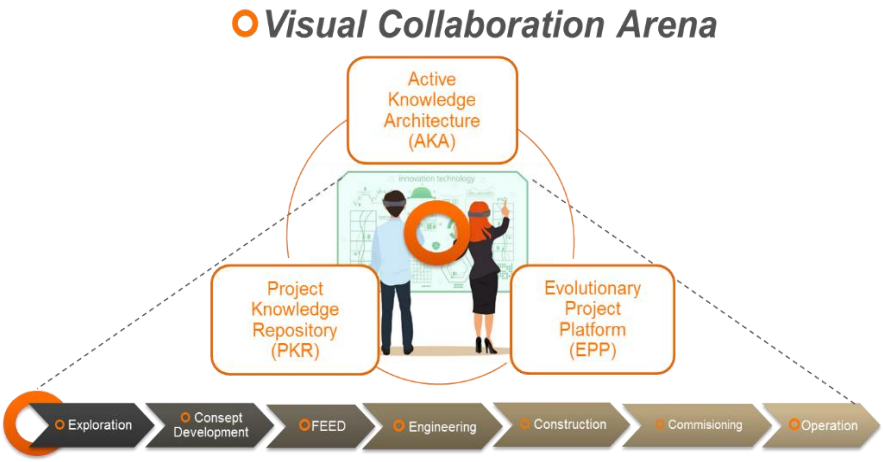

Fig. 1 New approaches and methods for project VCA design and operation.

Reference project and sector-solution AKAs will be built to ease front-end loading, supporting cyclic design and execution, and kick-starting new projects cutting calendar times and costs by factors. Fig. 1 illustrates the transformation of project design and

execution enabled by VCAs. One key characteristic of the new agile approach is best summarized as: use visual modeling rather than coding to capture global as well as local context. A second key characteristic is: supporting categories of users in capturing situations, decisions, dependencies, and local pragmatic knowledge by modelling role-oriented workspaces. To implement these characteristics software will be applied as an enabler for workspace and knowledge modelling of AKA-driven solutions, supporting enhanced communication, collaboration, configurations and competence transfer.
To effectively leverage the understanding and acceptance of holistic design of visual collaboration arenas and intelligent workspaces each major business, societal service and scientific method should be implemented in simple practical pilot demonstrators. Persons assigned to the team roles must share competence and be clever collaborators.

The AKM approach [4, 7] will have revolutionary impacts on business approaches, project methodologies, knowledge management and reuse, and ICT solution development across industries and public domains. Several customer pilots and AKA prototypes built by teams working at Model-Based, Architecture-Driven (MBAD) workplaces are developed for demonstrations, since 2007. The concepts and methods have for several years been used for experimentation in Norwegian research projects.

2.1 Design Modelling methods

A new agile approach and holistic design methodology for modelling of project life-cycle stages is fundamental for creating the integrating core knowledge base of the next generation enterprise VCA and EPP solutions. Knowledge modeling and management must be performed by teams involving leading practitioners, applying conceptual symbolic modelling languages. The holistic design approach should enable agile knowledge architecting, and collaborative learning and innovation, embracing new design and working concepts and methods. The challenges faced by industry and public domains to enable participation in multiple global projects require; ***an agile approach and holistic design for resolving complexity of work and knowledge management.***

3 Towards Holistic Project Design and Operations

Holistic design is more than a simple move from the modern to the post-modern, as it represents both an ontological change in the consideration of organizations and an epistemological shift in our understanding based on the emergence of CPS and VCA. The people involved in project and enterprise design and operations must adopt holistic thinking, and become familiar with the VCA concepts and AKM methods.

Holistic design of projects, products and processes implies modelling top-down to support planning and control, bottom up to capture work-sensitive data and context, and inside-out to create parameters for properties and capabilities across disciplines, partners and life-cycles. Supporting holistic design requires fine-grained knowledge modelling of workspaces and collaboration spaces, and support for conceptual design based on knowledge models of life-cycle operations and customer values.

Active knowledge models and knowledge architecture elements will be major assets in the growing Circular Knowledge Economy and the Digital Single Market [13, 14].

3.1 The evolution of Design Methods

Design methods has been a major domain for research and development, since the early 1980's when Beitz & Roth extended product design to embrace manufacturing, and Hubka introduced the principles of design embodiment to separate conceptual design properties and the balancing of discipline parameters and their tolerable values. Design embodiment implies that properties and parameters are modelled separately, and parameters are balanced across disciplines before they are embedded in objects.

The Holistic Design methodology must be implemented, adapted and validated in industrial pilot projects. The core knowledge domains, the design meta-knowledge, as illustrated in Fig. 2 is composed of concepts, capabilities, properties, qualities, shapes and volumes, features, eco-norms and rules, and life-cycle services.

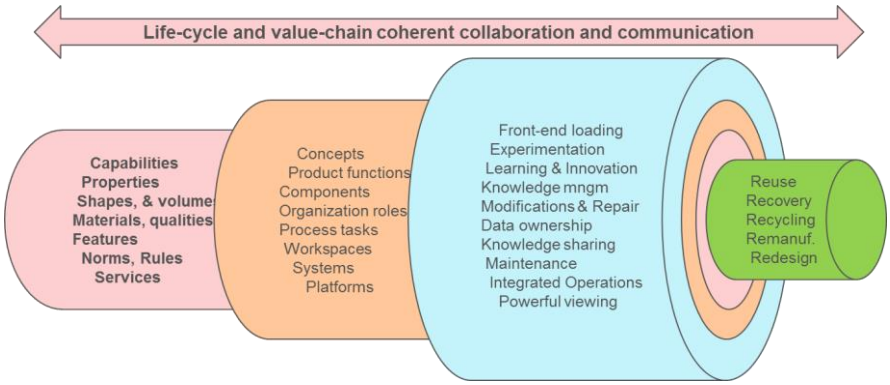

Fig. 2 Evolutionary VCA design of industrial meta-knowledge concepts.

We analyze the evolution of the collaboration arena from an engineering perspective. The central question considers the spectrum of engineering functionality available through the collaborative network at an engineer's workplace. Fig. 2 points to the rising spectrum of engineering and operational services available through the VCA. The evolution of the main concepts related to VCAs constitute a background for the novel paradigm-shifting concepts presented in section 5 and its sub-sections.

3.2 Towards a new generation of Computing Arenas

The discovery of human mental models created in our brain when performing or observing practical work and events enable humans to capture practical work-sensitive knowledge models from practical workspaces. Norwegian researchers [4, 7] invented an at-the-workplace graphic modelling approach for users enabling them to express their tacit knowledge and mental models as digital models as work is being performed. Workers are thus able to express, share, manage and transform tacit knowledge and workspaces as digital models. Digital models can be built and used to create and enhance our mental models enabling effective learning and collaboration, and reuse.

Important properties of our mental models are reflective views, repetitive task-patterns, replicative templates and reusable models for autonomous communication and collaboration. The impacts on computing, research and innovation, and project operations will be disruptive. Novel paradigm-shifting concepts and capabilities will impact industry and public sector computing, but will also impact sciences as digital knowledge models will enhance and enable new human team-working capabilities.

4 Selected industrial pilot

Holistic design of field operations and projects are being tested in the oil & gas industry. Building on the insight from many fields and exploration projects a holistic design approach to field development and operations is tested. The mission and operations design is the key to reduced cost and operational complexity, maximizing reliability and HSE qualities. Our pilot will combine the insights from the Woodside[1] project with state of the art knowledge capture and modelling, and to create a technical demonstrator that validates holistic design methods and enhanced life-cycle collaboration.

Woodside (SPE MS176813) has documented that the Capex can be reduced by 10-35%, and the Opex by 30-80%, and reliability increased from 95 to 97+ % by adopting low-manned/unmanned remotely operated facilities. The prerequisite for such success is that the operations philosophy and model is defined upfront in the concept phase, acknowledging that the operations model is a design driver, not as it is today, where the facility design drives the operations model. The architecture of the demonstrator consists of role and task specific collaboration spaces that support the early phases (Concept & FEED) design of a project. The operations model with facilities and resources and product design models support the stated mission, as illustrated in Fig. 3.

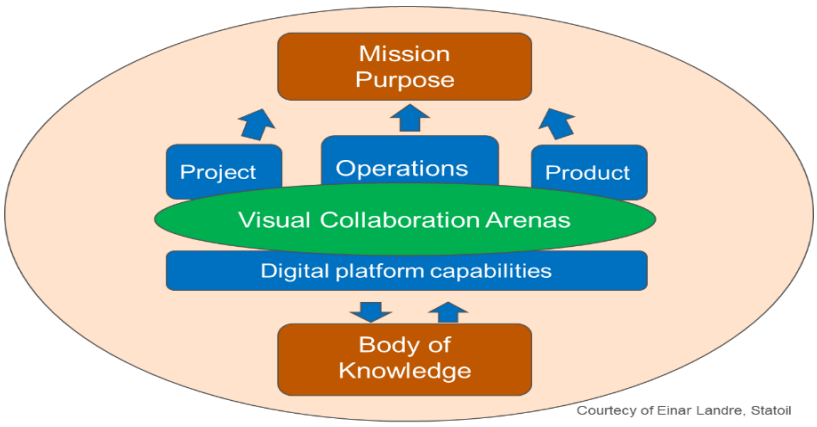

Figure 3 Capabilities and knowledge for designing Visual Collaboration Arenas.

[1] http://www.woodside.com.au/Pages/home.aspx

The architecture of the demonstrator consists of role and task specific collaboration arenas that support the early phases (Concept & FEED) design of a project that delivers an operations model and product design supporting a stated mission. The mission statement should be articulated on the form; a minimal manned, remotely operated installation that is profitable at a price point of $25/bbl.

Building on the insight from Woodside, a holistic approach to field development is the key to reduced cost and operational complexity, maximizing reliability and HSE qualities. Our proposal is to combine the insights from the Woodside project with state of the art knowledge capture and modelling, and to create a technical demonstrator that validates new holistic design approaches to projects, products and work environments.

5 Novel Paradigm-shifting Concepts

There are several paradigm-shifting concepts that will enable the design and operation of VCAs, and life-cycle workspaces to design novel approaches, methods, platforms and solutions, meeting the growing market needs, opportunities and challenges. The most important concepts enabling agile approaches and emergent solutions supporting concurrent project design and sustainable operations are:

1. *Enterprise Knowledge Spaces - multi-dimensional spaces simplify modelling, collaboration and parameter management*
2. *Context-rich Workspaces – simultaneous workplace design and execution*
3. *Active Knowledge Architecture - integrating approaches, methods, and services*
4. *Model-based, Architecture-driven Workplaces - configuring agile solutions*
5. *Concurrent Modelling and Operation – close the gaps in design and execution*

The major concepts, their properties, enabling capabilities and business impacts are illustrated in Fig. 4, and will be explained in the following sub-sections.

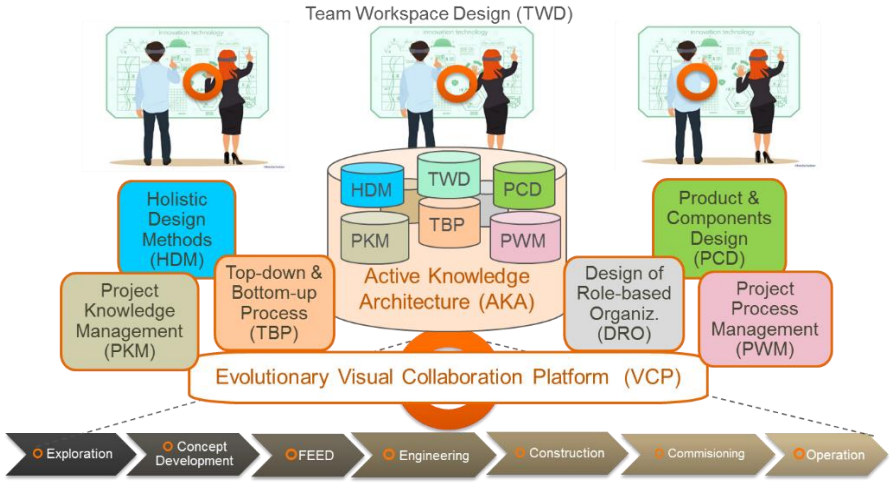

Fig. 4 Emergent networked enterprises – enabling life-cycle design and operation.

Multi-dimensional enterprise knowledge spaces, smart role-oriented organizations, workspace properties, AKA modelling, and the AKM methodologies and principles are explained in more detail in the entries of the AKM blog [4].

5.1 Enterprise Knowledge Spaces

Enterprise Knowledge is created in multiple dimensions by the people involved in the various enterprise activities and domains [7]. Smart networked enterprises cannot be built by acquiring or developing application software systems alone, and adaptive services cannot be delivered by current methods. Future development, use and value of ICT will be justified by externalizing and sharing situated enterprise knowledge, reusing role-oriented workspaces, and MBAD workplaces.

The nature of practical knowledge spaces and workspaces must be understood by users applying visual design modeling to capture work-centric knowledge and context. Active knowledge architectures, building active knowledge models, can support customer-driven development and situation-driven solutions and operations. Knowledge and experience sharing will be facilitated, and knowledge assets management and reuse will be decisive for future competitiveness and progress.

5.2 Role-specific Intelligent Workspaces

Existing organizations, composed of hierarchies, networks or static collaborating teams, were never designed to fit the design, manufacturing, construction, customer usability and life-cycle support of projects, products and operations to be delivered.

The people assigned to roles must be supported by reuse of MBAD agile workplaces, allowing them to perform at-the-workplace design modelling and task execution, closing the gaps between project stages by cyclic design and execution.
Local practical workspaces are developed over years by the most experienced and creative workers. Workspace mental models [5] consist mostly of tacit knowledge that can only be transferred by real collaborative practical training, and by providing the AKM methods and fine-grained modelling tools to the users. Graphic modelling of work-sensitive data and contexts enable humans to express their tacit knowledge as digital models, and use digital models to enhance their mental models for improved local work execution, coordination, collaboration and work management [8,9].

5.3 Active Knowledge Architecture

An agile holistic design approach, based on the AKM discoveries, concepts and methods, will provide practitioners with model-based workplaces, the required adaptive visual working environment, and the methods and capabilities needed. The Active Knowledge Architecture (AKA) is composed by holistic design thinking, agile approaches, novel design principles, and active models of enterprise knowledge spaces and role-oriented workspaces. Visual modeling and holistic design methods enable new approaches to application workplace and system solutions, whatever the application is.

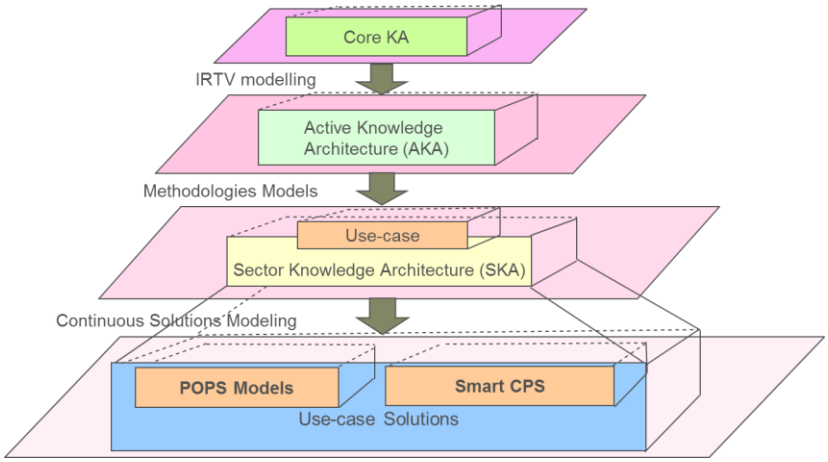

Fig. 5 Stages in AKA development, operations design and user value.

The Core Knowledge Architecture (CKA) is common to all knowledge architectures across sectors, methodologies and platforms, see Fig. 5 above. By graphic modelling of knowledge spaces, applying the IRTV language [9], the design of the operations and project- specific AKA is supported. Exploring more fields and executing more projects will create a reference sector-specific AKA. Building active models of partner approaches and methods for product and process design and models of roles and workspaces can create networked enterprise reference solutions for the entire life-cycle.

5.4 Model-based, Architecture-driven Workplaces

Workplaces of application systems are hardcoded, so what users can adapt, change and add is very limited as it would imply changing the logic of compiled code.
MBAD agile workplaces have been successfully prototyped in five pilots. Solution development is based on collaborative visual modeling at architecture-driven workplaces, involving teams for architecting, application and methods modelling, and platform building. Collaborative open innovation and learning, and continuous design and operation of emergent networked solutions is enabled. Agility and emergence can be achieved by building MBAD workplaces, providing capabilities for autonomously extending and modifying AKMs and AKAs affected by evolution and change.

5.5 Concurrent Modelling and Operation

Capturing role-specific workspaces and knowledge spaces, applying holistic design methods, is performed by teams interacting and collaborating to influence the shared active models of approaches, methods, application capabilities and domain aspects [7].

Design modelling will create conceptual objects, capabilities and properties. and discipline parameters, features and values in separate views, supporting design embodiment and creation of design, configuration and collaboration rules. Building and

operating classes and categories of knowledge assets will be facilitated. The current life-cycle gaps in design and operation can be closed, and users can experiment with variants and families of solutions. Visual work environments allow users to observe and monitor status of work at related human and digital roles. Traceability, decision-support, predictability and assessment of trends and situations will give users enhanced capabilities to deal with uncertainties, risks and maintenance.

6 Contributions to Sustainability

The model-based, architecture-driven solutions design and delivery is ideal for what is described as the reindustrialization of European industries. Instant collaboration, open innovation [6], workplace training and learning, and rapid competence transfer and adaptation to new environments and situations are just a few of the demands met. As illustrated in Fig. 6, the common approach, methods, infrastructures and solutions to all industrial and public enterprises can be composed by the architecting team applying fine-grained modelling methods. Adding designer and user teams, extending modelling to cover aspects of product, organization, process and system, enable the design of sector-specific methods and architectures. In the sector space, adapting components of the CPPD design methodology [7, 9], the teams will be able to design sector-specific solutions, supported by classes and categories of knowledge assets.

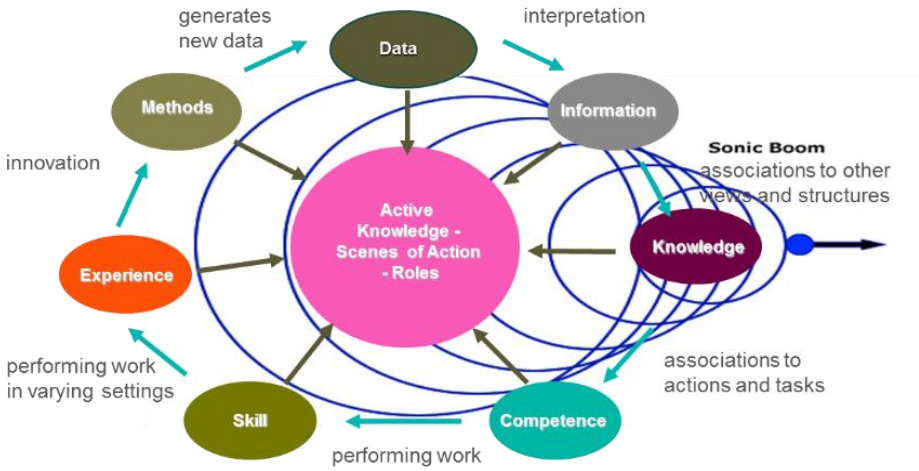

Figure 6 Knowledge concepts, classes and categories will be built and reused.

Components of the CPPD design methodology to build and manage rule-governed object-classes have been prototyped, whereas components for managing and reusing ideas and categories across AKM classes of different kinds of objects need more research. Workspace models enabling autonomous knowledge management over life-cycles and value- and supply-chains can revolutionize industrial and societal services.

7 Conclusions

To meet the rapidly growing challenges and opportunities industry and public sectors are facing [12,13] they are in urgent demand for new ways of providing and applying computing power. We believe the AKM technology has the concepts, capabilities and properties required to provide new agile approaches, adaptive methods, visual work environments and new ways of computing. Future research, experimentation and innovation will focus on developing and providing sector and life-cycle agile approaches, holistic design methods, knowledge architectures and open modelling and computing platforms. Active knowledge models of approaches, methods and solutions will be normalised, enhanced and used in both private and public sector projects.

We will build partner networks for VCA component and knowledge asset development and delivery, for platform composition, operation and support, and for methodology integration and adaptation. Collaborative Learning and Training, Concurrent Design and Operations, and Open Innovation and Experimental Learning will be enabled by paradigm-shifting approaches, methods and solutions.

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