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► **To cite this version:**

| Marcus Specht. RTST Trend Report: lead theme Contextualisation. 2012. hal-00722748

HAL Id: hal-00722748

<https://telearn.hal.science/hal-00722748>

Submitted on 3 Aug 2012

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D1.7

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Edited by
Marcus Specht



STELLAR

Amendment History

Version	Date	Contributor(s)	Modification
1.0	30/05/2012	Marcus Specht (OUNL)	Revision according to peer reviews.
0.9	11/05/2012	Bernardo Tabuenca, Stefaan Ternier, Marco Kalz, Dirk Boerner, Birgit Schmitz, (OUNL)	Revision and additions about theoretical background.
0.7	11/05/2012	Bernardo Tabuenca, Stefaan Ternier, Marco Kalz, Dirk Boerner, Birgit Schmitz, (OUNL)	Contribution to subsection on specific technology trends.
0.1	01.05.2012	Marcus Specht (OUNL)	First Version

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WP1 | D1.7

RTST Trend Report: lead theme Contextualisation

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public report	final	1.0	31/5/2012	M40
audience & type	status	version	doc date	due date

Trend context learning

keywords

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1 Introduction and Background

When starting the NoE STELLAR about 4 years ago in the Description of Work some of the main aspects of the Grand Challenge Cluster of Contextualisation of Learning have been identified and described. Two of the main assumptions and their consequences will be also reflected and discussed in this trend-scouting report.

“Learning is woven into everyday life making use of new technologies. As a consequence tools, resources and systems needs to be contextualized. How can we use technologies to deepen the learning experience in a specific learning context?”

This starting point reflects the trends for computers becoming more ubiquitous and embedded in everyday life and usage settings. 20 years after Marc Weiser’s visionary statement about the disappearing computer it becomes more and more clear that the technologies we see appearing are components of this broader vision. The usage of technologies in everyday situations and especially in educational settings necessarily has to define the role, scope, impact and efficient usage of these. Therefore the linking and good practice integration of ubiquitous, mobile, and ambient technologies in educational settings has to be defined by their context of use.

In the first part of the trend scouting report we will outline some of the recent research works on contextual learning and how context is interpreted in educational practices.

Several technology trends play an important role for identifying the context of learning, adapting to the context, and interacting in context with learning systems. These technologies and their role are outlined in the technology trends section of this report. Relevant technologies are for example sensors, tangible computing, augmented reality, and smartphones. Defined as an original added value of mobile learning to have access to information and services anywhere and at anytime it becomes more and more important to understand how these technologies are related to the actual characteristics of the real life situation of the user.

“Interplay between formal and informal learning needs to be instrumentalised (orchestrated) with physical artefacts, mobile devices and the configuration of physical and virtual space.”

By the introduction of social and mobile media the usage of digital media in informal learning settings has grown immensely in the last years. Especially the younger generation has adopted these technologies for everyday leisure and communication. More and more the relevance of these technologies, and the impact they have, became clear in recent media studies. The integration of these

technologies in blended learning scenarios combining formal learning in the classroom and informal learning aims at several theoretical underpinnings of technology enhanced learning. The problems and potential of orchestration with new technologies has been discussed in an orchestration whitepaper (Dillenbourg, 2011). In this trend scouting report we will therefore mainly focus on the aspects of using technology for linking learning contexts in informal and formal settings.

“How can we use technologies that link learning contexts and support learning trajectories across multiple contexts with mobile, ambient or ubiquitous technologies?”

In summary this trend-scouting report highlights different design dimensions of contextualizing learning, which include:

- Designing Educational Context: the components and constituents of the educational setting, which also have to be orchestrated in an instructional design or the process of orchestration (Luckin, 2010, Specht, 2009).
- Bridging and linking learning contexts for seamless learning support: Wong et al. define design dimensions of seamless learning experiences and which gaps they identify and what challenges must be tackled to create seamless learning experiences (Wong, 2011).

Related research questions are:

- How can we build new islands of stable context for learning when the classroom is removed?
- How can contextualised learning support novel experiences?
- How can we link both virtual and real learning contexts via technology?
- Are learning standards and interoperability relevant in contextualised learning support?

2 Understanding and using context in TEL

“Context is everything”. In nearly every scientific discipline ranging from psychology to archaeology claims about the importance of context are made. Linguistics makes two claims about context: Context is defined as a) the text in which a word or passage appears and which helps ascertain its meaning b) the surroundings, circumstances, environment, background or settings which determine, specify, or clarify the meaning of an event. Several research communities related to TEL have recently worked on the role or the definition of context and how support learning in context (Luckin, 2010).

2.1 Models in Context-Aware Computing

The field of context-aware computing has developed a variety of context definitions mostly starting from location or object context. In a pragmatic approach Zimmermann et al. (2007) give a workable definition of context: “any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between the user and the application, including the user and the applications themselves”. Moreover, Zimmermann clustered context into five fundamental categories:

- **Individuality.** Includes information about objects and users in the real world (with respect to users, their profile can include preferences, acquired-desired competences, learning style, etc.). This facet of context can also refer to information about groups and the attributes or properties the members have in common.
- **Time.** Refers to tempo coordinates. Ranges from simple points in time, to ranges, intervals and a complete history of entities.
- **Location.** It can be referred to the physical and/or virtual spatial coordinates. They can be described based on quantitative or qualitative location models, which allow working with absolute or relative positions respectively.
- **Activity.** Refers to what does the entity want to achieve and how. Reflects the entities goals, tasks and actions.
- **Relations.** Captures the relation an entity has established to other entities, and describes social, functional and compositional relationships.

Based on the mentioned parts of context, context-aware systems have so far strived to (a) adapt user interfaces, (b) filter information selection and presentation, (c)

increase the precision of information retrieval, (d) discover services, (e) make the user interaction implicit, or (f) build smart environments. In the 90's quite some work has been done on adaptive educational hypermedia environments making use of the task context, the preferences of learners, and or the previous knowledge of learners these systems adapted mostly to the identity context dimension.

Generally speaking the idea of context-aware systems originated out of ubiquitous computing and the adaptation of a computer system to its changing environment. Computers that become mobile or embedded in different environments should basically be able to sense their environment and react to environmental changes.

This idea is also rooted in Marc Weiser's vision of the disappearing computer:

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." (Weiser, 1991)

As one famous example, the so-called dangling string was an 8-foot long plastic string hanging from the ceiling in the corner of the hall. The string was connected to a little electronic motor that rotated the string depending on the computer network traffic in and out of the laboratory. The string rotated at different speeds and produced different sounds depending on the traffic.

In the last 50 years the relation between available computing devices and humans using those devices has been inverted. While in the 1960s only several people used big mainframe computers today everybody uses several computers daily, even without noticing, in watches, train ticketing machines, or mobile phones. As soon as all these computers are embedded and integrated into everyday artefacts the real world context of the artefacts becomes important.

Already in the 1980s in XEROX PARC research lab, different alternatives about ubiquitous computing devices and how to make computers disappear in our daily environment have been explored. Since then, many applications and even generic frameworks have been developed to enable the implementation of sensor-based interactive artefacts embedded in everyday interactions. As it has been mentioned earlier, Greenfield (2006) describes a whole range from coffee cups sending their coffee temperature to the potential drinker, to small plastic bunnies that sense when and where your kids are on their way home from school. Furthermore, technical solutions have been developed about core problems of accessing and integrating sensor information (sensor fusion), the identification of different contexts based on the sensor information, and even about different models for triggering actions of a computer system based on different contextual changes.

For TEL these technology developments have most prominently been picked up by works in the area of field trip in which students can

- communicate with remote locations,
- collect data in the field with mobile devices and relate these to assignments and tasks given in an instructional context.

In Technology Enhanced Learning the term “context” has recently gained new importance due to the popularity of mobile devices and the developments in ubiquitous and context-aware computing in the last years. Research on context-aware computing and developments of mobile and sensor technologies have opened up new opportunities for supporting learning in context.

A recent Alpine Rendezvous workshop report has collected some of the relevant works in the field of contextual and location-based mobile learning: Education in the wild: contextual and location-based mobile learning in action (Brown et al., 2010). As one main conclusion of the presented works certainly the augmentation of the learners real-world environment can be seen as one trend, which will also be explored in this report. Context-aware technologies in this sense give an option to augment the learner’s environment with relevant and supportive information and services.

There are several challenges connected to the research on context and learning. Greenfield (2008) highlights some prospects and perils in context-aware and mobile learning support. While location-based learning is a first easy step into the direction of a more contextualised learning support the context-detection and real contextual awareness is related to “AI” hard problems. The intuitive integration of a variety of cues that humans are able to perceive is a still highly challenging problem for computer-based context detection.

2.2 Educational Models of Context

From a TEL perspective several models for designing and making use of technology for enriching learning experiences have been developed. For this trend-scouting report we have selected two models, which explicitly describe dimensions of design of contextual learning. The two models selected is the AICHE model (Specht, 2009) which describes contextualized learning support based on a model of context-aware computing and the related educational processes. The Ecology of resources framework from Luckin (2010) describes context more seen from the perspective of a complete ecosystems in which affordances and scaffolding can be applied for contextualized learning support. Without doubt there are several other models and works relevant for this discussion as Koole’s FRAME model (2009), the mobile social media framework of De Jong et al (2008), or especially the works of Sharples (2002,

2007) with a theory of learning for the mobile age. For underpinning the main trends and building a theoretical base for this report AICHE and EoR have been selected due to their focus on definitions of context and the use of context in educational design.

2.2.1 Ambient Information Channels (AICHE)

The AICHE model (Specht, 2009) allows describing patterns of contextual learning support in a generalised way. It integrates research of the last ten years about context-aware computing, information modelling, adaptive educational hypermedia, instructional design, and human computer interaction.

AICHE gives a simple metaphor of information channels that are ambient all around us. The underlying assumption is that it is simply possible to access any kind of information or computational service out of the “cloud”. When we can access any kind of information as documents, messages, annotations, and services in a given situation we have the freedom to plan for educationally sensible interactions and do not need to think about technical barriers. The channels coming out of the cloud can transport multimodal information when bound to displays as visual, auditory, haptic, gustatory, or olfactory. Displays can also become simplified indicators of information as a light indicating contextual information in an abstracted way.

All channels have a set of meta-information (contextual information) connected to them as soon as they are instantiated. Basically this meta-information holds all contextual information about a channel like location, id, content, environment, relations, or activity. Channels can be bound to artefacts in the physical environment and these artefacts can be configured to indicate the channel information in a special way. This basically enables a flexible delivery and acquisition of information to and from the different channels.

Artefacts, channels, and users can make use of sensor information. As a simple example a channel and a user would have a location sensor attached to them and the channel would continuously scan for the best way to be displayed at the changing location of the user.

With the help of defined AICHE processes like aggregation, enrichment, synchronisation, and framing contextual learning patterns can be described in a simplified though still educationally motivated and closely linked to implementation strategies. Aggregation enables contextual learning support to use a variety of sensor information and combine the sensor data with data and information in the process of enrichment. In the design of contextual learning applications this

basically leads to the description of the sensor information that is used for delivery as augmentation of the learners physical environment or to the use of sensor information that enables the selection and adaptation of other information channels.

The process of synchronisation describes the ways in which these information channels are combined, selected, filtered and how the synchronisation between the learner's context and the available information channels is achieved. In the process of synchronisation also the logic of context-aware and context-adaptive learning support is modelled. The approach of modelling contextual learning systems only via information channels and contextual meta-data enables the design of educational models ranging from programmed instruction, to more flexible scaffolding, to more explorative and constructivistic applications. In this model context is the linking entity, which is used for information selection, adaption of the learning logic as also the linking between learning situations.

2.2.2 Ecology of Resources Design Framework (EOR)

In her model on the ecology of resources, Luckin (2010) looks at several changes and extensions of context from a multi-disciplinary and also multidimensional perspective. Resources in a future learning ecology are distributed across devices and multiple computer-based technologies, multiple learners, a range of locations, multi-dimensional user modelling and scaffolding that involves meta-cognition, affect, and cognition, broader ranges of subject matter.

As the core concepts for the model Luckin defines the Zone of Available Assistance (ZAA), which describes the variety of resources that could provide assistance to a learner and the Zone of Proximal Adjustment (ZPA), which represents the subset of resources from the ZAA that are appropriate to the learner's needs.

In her model Luckin distinguishes three types of resources a) Knowledge and Skills, b) Tools and People, and c) Environment. The availability and usefulness of these resources are filtered by a variety of different filters, which range from formal filters like curricula to classroom arrangements and schedules. Furthermore resources and filters influence each other via relationships. In this ecology of learning resources, the "More Able Partner" (MAP) role can be taken by technology, peers or educators.

In the process for designing rich learning experiences through technology Luckin specifies three phases, with several steps:

- **Phase 1: Create an Ecology of Resources Model** to identify and organize the

potential forms of assistance that can act as resources for learning.

- Step 1 - **Brainstorming** Potential Resources to identify learners' ZAA
 - Step 2 - Specifying the **Focus of Attention**
 - Step 3 - **Categorizing** Resource Elements
 - Step 4 - Identify potential Resource **Filters**
 - Step 5 - Identify the **Learner's Resources**
 - Step 6 - Identify potential **More Able Partners**.
- **Phase 2: Identify the relationships within and between the resources produced in Phase 1.** Identify the extent to which these relationships meet a learner's needs and how they might be optimized with respect to that learner.
 - **Phase 3: Develop the Scaffolds and Adjustments** to support the learning relationships identified in Phase 2 and enable the negotiation of a ZPA for a learner

Luckin describes a broad range of practical case studies and gives clear guidelines and steps for educational designers on how to design ecologies of resources which take a holistic perspective on the learning context. The model is highly flexible for using any kind of technological service but also classical learning aids and any kind of learning resource. Also the linking between different learning contexts or situations is discussed from a holistic, broad, and interdisciplinary perspective. Nevertheless Luckin defines context with respect to an individual person but that is constituted via billions of interactions that they have with the resources of the world.

2.3 Bridging Contexts: Seamless learning support

While both models above (AICHE and EoR) conceptualize the context around the individual and try to understand the nature and forming of context recent approaches from the field of ubiquitous learning support have put the focus on linking different situations and learning contexts. From that perspective the notion of the “seams” in learning support and the role of technology in this becomes more prominent.

Wong et al. (2011) focus on the role of technology in seamless learning supported by 1:1 (one device per learner) settings. In an analysis of 49 papers, Wong (2011) identifies ten dimensions of Mobile Seamless Learning (MSL) relevant for future research:

- (MSL1) Encompassing formal and informal learning;

- (MSL2) Encompassing personalised and social learning;
- (MSL3) Across time;
- (MSL4) Across locations;
- (MSL5) Ubiquitous knowledge access (a combination of context-aware learning, augmented reality learning, and ubiquitous Internet access);
- (MSL6) Encompassing physical and digital worlds;
- (MSL7) Combined use of multiple device types (including “stable” technologies such as desktop computers, interactive whiteboards);
- (MSL8) Seamless switching between multiple learning tasks (such as data collection + analysis + communication).
- (MSL9) Knowledge synthesis (a combination of prior + new knowledge, abstract + concrete knowledge, and multi-disciplinary learning);
- (MSL10) Encompassing multiple pedagogical or learning activity models.

On bridging the gaps within the named 10 dimensions, a technological, pedagogical, and learner centric perspective can be taken according to the authors. Nevertheless they see the necessity to approach all of these seams or gaps.

By advocating MSL, it is our intention to combine the technological resources (essentially MSL5 and MSL7) and pedagogical means (essentially MSL8 and MSL10) to “ignite” (scaffold, nurture, and support) our learners’ “inner fire” of sense making or sense creation (relevant to MSL9). Such dispositions are stimulated by new information (either intentionally or incidentally) accessed or sensed anytime, anywhere (MSL3 and MSL4), and within any context (MSL1, MSL2, and MSL6), thus enabling the learners to experience genuinely holistic learning. (Wong, 2011, page 24)

3 Technology trends in Context and TEL

Based on the theoretical underpinning from above we have studied several recent reports and studies on important issues in contextualized and seamless learning support.

In 2006 a group of 17 internationally recognized researchers wrote a report (Chan et al., 2006) on a paradigm shift in TEL. In the abstract of the “One-to-One technology-enhanced learning: an opportunity for global research collaboration” report they state:

*Over the next 10 years, we anticipate that personal, portable, wirelessly-networked technologies will become ubiquitous in the lives of learners — indeed, in many countries, this is already a reality. We see that ready-to-hand access creates the potential for a new phase in the evolution of technology-enhanced learning (TEL), characterized by “**seamless learning spaces**” and marked by **continuity of the learning experience across different scenarios** (or environments), and emerging from the availability of one device or more per student (“one-to-one”). One-to-one TEL has the potential to “cross the chasm” from early adopters conducting isolated design studies to **adoption-based research and widespread implementation**, with the help of research and evaluation that gives attention to the digital divide and other potentially negative consequences of pervasive computing.*

Beside the focus on seamless learning support the authors also highlight some features of one-to-one technology and its potential impact on education and learning.

- (1) Portability that takes the computer to different sites and allows movement within a site so that the bounds of the classroom are extended to the limits of wireless networks;*
- (2) Social interactivity supported by mobile and wireless technologies that enables direct peer-to-peer communication, data exchange, and face-to-face interactions and collaboration;*
- (3) Customisation to the individual’s path of investigation;*
- (4) Context sensitivity that automatically logs and aggregates usage for designing collaborative filtering systems and predictive user interfaces;*
- (5) Connectivity that creates a true shared environment via a common network*

for data collection among distributed devices;

(6) Combining digital and physical worlds with sensors, smart rooms, and ambient environments that capture real-world information of users, devices, and locations (geographical information systems) and represent it in a format that is usable in the digital realm.

Horizon Reports Technology Trends	
▼ • 2004	<ul style="list-style-type: none">• ◊ Learning Objects• ◊ Scalable Vector Graphics• ◊ Rapid Prototyping• ◊ Multimodal Interfaces• ◊ Context Aware Computing• ◊ Knowledge Webs
▼ • 2005	<ul style="list-style-type: none">• ◊ Extended Learning• ◊ Ubiquitous Wireless• ◊ Intelligent Searching• ◊ Educational Gaming• ◊ Social Networks and Knowledge Webs• ◊ Context Aware Computing/Augmented Reality
▼ • 2006	<ul style="list-style-type: none">• ◊ Social Computing• ◊ Personal Broadcasting• ◊ The Phones in their Pockets• ◊ Educational Gaming• ◊ Augmented Reality and Enhanced Visualisation• ◊ Context Aware Environments and Devices
▼ • 2007	<ul style="list-style-type: none">• ◊ User Created Content• ◊ Social Networking• ◊ Mobile Phones• ◊ Virtual Worlds• ◊ New Scholarship• ◊ Massive Multiplayer Educational Gaming
▼ • 2008	<ul style="list-style-type: none">• ◊ Grassroots Video• ◊ Collaboration Webs• ◊ Mobile Broadband• ◊ Data Mashups• ◊ Collective Intelligence• ◊ Social Operating Systems
▼ • 2009	<ul style="list-style-type: none">• ◊ Mobiles• ◊ Cloud Computing• ◊ Geo Everything• ◊ The Personal Web• ◊ Semantic-Aware Applications• ◊ Smart Objects
▼ • 2010	<ul style="list-style-type: none">• ◊ Mobile Computing• ◊ Open Content• ◊ Electronic Books• ◊ Simple Augmented Reality• ◊ Gesture Based Computing• ◊ Visual Data Analysis
▼ • 2011	<ul style="list-style-type: none">• ◊ Electronic Books• ◊ Mobiles• ◊ Augmented Reality• ◊ Game-Based Learning• ◊ Gesture Based Computing• ◊ Learning Analytics

In its yearly reports the Horizon Project analyses and describes main technology trends and their impact on teaching, learning, research, or creative expression.

In the last 6 years the horizon report identified key technologies in every year and classified them according to their time horizon until adoption.

Since 2004 developments and applications around context-aware computing, multi-modal interfaces, ubiquitous wireless access, context-aware computing and augmented reality have been described relevant. In the last years Mobiles became a repeating topic in different variations, cloud-based computing, geo-everything, electronic books, as also new forms of interaction have been described in these reports.

In 2009 the Horizon Report explains several technologies, which will “significantly impact the choice of learning focused organisations within the next five years” (Horizon Project, 2009).

The six topics highlighted in the 2009 report were Mobiles, Cloud Computing, Geo-

Everything, the Personal Web, Semantic-Aware Applications, and Smart Objects.

Over all the years the reports also have identified key trends related to the technology trends identified. In 2011 key-trends and challenges have been identified as:

- Abundance of resources and relationships is more and more challenging for educators.
- People expect to be able to work, learn, and study whenever and wherever they want.
- A world of work, which is increasingly collaborative, also challenges to reflect on the structure of student projects.
- Digital media literacy continues its rise in importance as a key skill in every discipline and profession.
- Economic pressure challenges traditional models of education and educational institutions.

In general the usage of mobile technology has an impact and plays an important role in many of these developments. Which also links back to the one-to-one perspective and the foreseen developments.

On the one hand, the mobile technology and embedded technology enable **ubiquitous access to information** and integrate information display and access in traditionally static or manually controlled displays and visualisation tools as digital boards. This does not only change the availability of computational power in the classroom and the availability of content, but also has high implications on the design and the structuring of physical spaces as classrooms today. Furthermore, through the integration of new forms of human computer interaction this also has implications for the social relationships and the group interactions in the classrooms. In that sense, the ubiquitous and cloud-based access to information is linked to the topic of seamless integration of learning support and bridging the gaps between different learning contexts. Furthermore mobile technology enables the linking of informal learning and non-classroom activities with traditional learning.

On the other hand, the use of mobile devices and embedded technology also support the **integration and use of these technologies in classically not “computerised” contexts** of work, leisure, and learning. In that sense the linking between classical physical environments and digital media are a key research challenge, which are linked to technology trends as augmented reality, geo-everything, data-mashups, or smart objects. In general these technologies and

trends aim at the support of deepening and broadening learning experiences in context more than bridging between contexts.

Additionally especially mobile technologies open up new opportunities for **linking and bridging between contexts**. This is linked to the seamless support of learning activities distributed across time, space, and social contexts.

As an additional step for this trend scouting report an expert concept mapping study has been done. The detailed methodology and the results have been reported in Börner et al. (2010). The expert concept mapping methodology offers a structured participative conceptualization approach to identify clusters of ideas and opinions generated by experts within the domain of mobile learning. Using the concept mapping approach the study identified educational problems and the related domain concepts in mobile learning. In the concept mapping study 20 internationally recognized experts contributed by reactions on the research questions:

RQ1. What are the educational problems that mobile learning is trying to solve?

RQ2. Which problem clusters can be identified and how are they emphasized?

RQ3. How are the different problem areas related within the overall research domain of mobile learning?

The core educational concepts of mobile learning identified are: “access to learning”, “contextual learning”, “orchestrating learning across contexts”, “personalization”, and “collaboration”.

Throughout the report of the expert group in 2006, the Horizon reports of the last years, the expert concept mapping study, as also other reviewed works we have identified two main clusters of research focus. In the following, we have selected some technology trends for which dedicated literature reviews have been done in the context of this trend scouting report. The technologies have been selected according to their contribution to the two main identified issues from above, i.e. the **deepening of learning experiences in context** and the **linking of learning experiences across contexts**.

The detailed reports about the undertaken work are published or are currently under review for publications. For each of the topics a summary of one page is reported here. The selected technology and research trends are:

Deepening learning experiences by:

- Mobile augmented reality (Journal publication in 2011, Specht et al., 2011)
- Sensor Technology for usage and activity tracking (Journal publication under

preparation for 2013).

- Ambient and Situated Displays (Literature review submitted to Computers & Education, 2011)
- Tangible Objects for Learning (Literature review submitted to EC-TEL 2012)

Linking learning contexts by:

- Location-based and contextual Learning (Report published from ARV 2010, Brown et al., 2010)
- Smartphones as generic learning tools (publication under preparation for International Journal of Mobile and Blended Learning, 2012).
- Mobiles Serious Games (Literature review submitted to International Journal of Technology Enhanced Learning, 2012)
- Cloud computing for seamless learning support (Book publication under preparation)

3.1 Mobile Augmented Reality

Based on Specht, M., Ternier, S., & Greller, W. (2011). Mobile Augmented Reality for Learning: A Case Study. Journal Of The Research Center For Educational Technology, 7(1). Retrieved January 18, 2012, from <http://www.rcetj.org/index.php/rcetj/article/view/151>

Until recently, augmented reality (AR) applications were mostly available for powerful workstations and high power personal computers. The introduction of augmented reality applications to smartphones enabled new and mobile AR experiences for everyday users. Because of the increasing pervasion of smartphones, AR is set to become a ubiquitous commodity for leisure and mobile learning. With this ubiquitous availability, mobile AR allows to devise and design innovative learning scenarios in real world settings. This carries much promise for enhanced learning experiences in situated learning.

Milgram and Kishino (1994) describe augmented reality (AR) as “relating purely virtual environments to purely real environments”. Like context-aware systems, augmented reality applications make it possible to filter information and present information overlays relative to the user’s current context (Zimmermann et al., 2005, 2007). Information in context can be filtered according to location, movement path, facing direction, object in focus, time period or according to meta-information such as the learner’s personal interests or profile.

In addition to this conceptual model of AR applications, an engineering perspective is required to understand the technical components and their role in mobile AR

systems for learning. In their description of the history of mobile AR Wagner et al. (2009) have identified the following technical components of mobile AR systems as being important:

- *Flexible Display Systems*: this includes head mounted display systems, camera phones, and hand-held projectors. Display technologies become increasingly more flexible and cheaper to produce. These technologies enable the augmentation of everyday vision of mobile users.
- *Sensor systems* in mobile devices like gyroscopes, GPS, electronic compass, cameras, microphone, as well as indoor location tracking systems.
- *Wireless networking protocols and standards* supporting indoor and outdoor augmentation settings. These also enable multi-user real time interaction in the augmented reality.
- Mobile Phones with computational power to do real time visualization of 3D objects and overlays on a standalone device.
- *Tagging and tracking technologies* with six degrees of freedom, multi-marker tracking, and hybrid tracking systems. This is also related to one of the most researched areas in AR, the registration problem (Bimber, 2005). It describes the problem of linking the real world perception of a mobile AR user and the presentation of the augmentation layer. Thus, the registration problem is closely linked to what we have been referring to as synchronisation.
- *Linking of location-based AR information* in storytelling and gaming approaches. There is an urgent need when AR is used for learning support to link AR experiences with instructional designs or at least with task structures and sequencing approaches. Storytelling and gaming approaches are currently the most prominent approaches.
- *Flexible layer-based AR browsers* with integration of social media. Basically, AR systems must also build on existing information channels and can present existing information to users in a new kind of user interface. Therefore, implementations of mobile AR for learning must enable open interfaces to existing content and services.

(Mobile) Augmented reality can be applied in various educational domains. It can help learners to gain a deeper understanding, experience embedded learning content in real world overlays, or explore content driven by their current situation or environmental context. Most prominent examples support exploration of the physical environment with different topics of interest, e.g. history, arts, technology, biology, astronomy and others, or by enriching artefacts in the physical

environment with AR techniques. In general, AR technically is divided in marker-less and marker-based AR to register digital content for real world orientation and placement. A number of educational patterns are related to the interaction patterns discussed earlier. The patterns described below connect an educational objective to the usage of certain dimensions of context (Specht, 2009) in synchronising the augmented reality layer with real world learning situations. They are therefore positioned via these connection points in a matrix (Figure. 1).

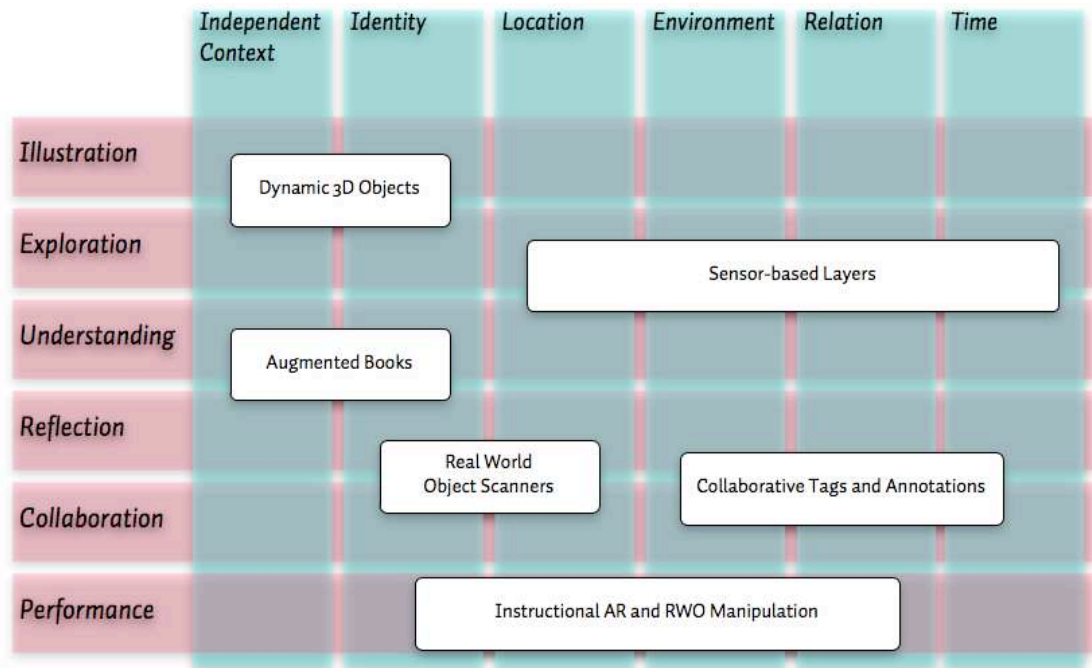


Figure 1: Augmented reality design patterns and educational purpose.

3.2 Sensor Technology for usage and activity tracking

Tracking information about learners and their learning progress is at the core of computer based educational systems. Especially adaptive educational systems used assessment and user tracking for personalisation of interaction with the learner. Adaptive feedback, navigation support, and tutoring of computer-based systems are in most cases based on the assessment of performance of learners or on user preferences (Brusilovsky, 1996).

Different forms of data acquisition range from using learner’s interaction history, analysis and data mining of footprints, to highly sophisticated assessment processes integrating a variety of methods. In general, the more data is available about learner activities, the more accurate adaptive systems can adapt to learners and support personalised learning.

Going one step further, users of mobile sensor technologies start to collect private datasets for reflection and monitoring of daily activities as in the Quantified Self movement. While partly the collected data is based on individual protocols, logbooks, and notes also a whole set of best practices and technical tools, sensor gadgets, and mobile apps are described to track user behaviour. The application fields of sensor tracked data range from energy, fitness, mood, productivity, or relationship tracking, as also tracking learning progress.

While the idea of using sensors has been used already quite some time in physical education and advanced sports training, life logging and sensor tracking applications nowadays are used in a wide range of application fields such as health, nutrition, life-style, fitness, sleep, or productivity.

New kinds of sensor devices like the Fitbit support users monitoring their health, weight, sleep behaviour and other parts of their daily living. Technically it is possible to track activities, geo-spatial movements, physical activities, social relationships, as also detailed bio-physiological data about learners and their daily practices. Nevertheless there is a core question about the underlying mechanisms and how these new forms of user tracking and the feedback based on this information can be best integrated in instructional designs and educational systems.

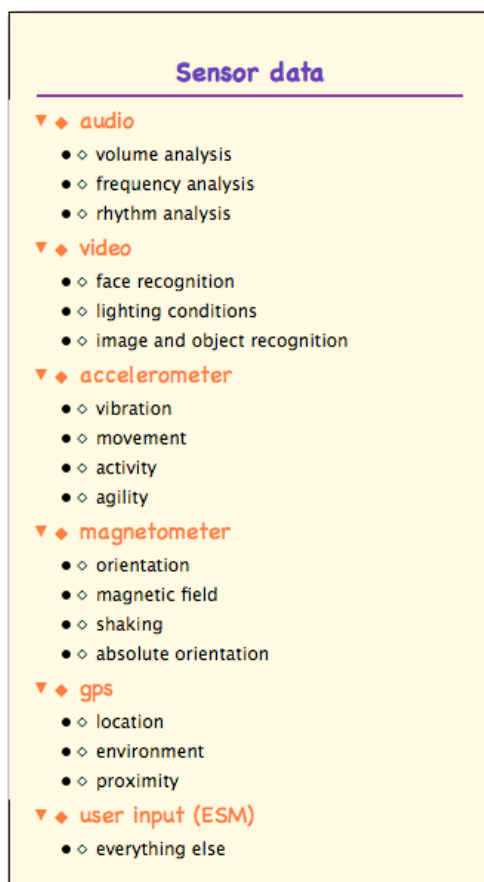


Figure 2: Sensor data and use for context information

Recently Goetz (2011) has described the power of feedback loops and real-time sensor feedback for human behaviour change ranging from power consumption, medication, health monitoring, and other fields. As a core principle even redundant information visualised in feedback-loops in the right context is an efficient mean in self-regulation.

An overview of types of sensor data (audio, video, accelerometer, magnetometer, GPS, user input) and how this raw sensor data is used for analysis of user behaviour and feedback in educational applications can be seen in figure 2.

Furthermore sensors play a crucial role in contextualisation. Sensors allow users to get information about their environment, enable new forms of user interaction, and connect the real world with information

objects.

The different types of sensor data and also the secondary information that can be inferred from the raw sensor data has been used in the literature in a variety of domains for user feedback and training purposes. Application domains range from Sport, health education, music training to special abilities training as Stress, Autism, ADHD, Migraine and others.

3.3 Ambient and Situated Displays

To approach the abstract concept of *ambient displays* it is beneficial to start with a definition of its compounds. The adjective *ambient* is defined as “relating to the immediate surroundings of something” or “relating to or denoting advertising that makes use of sites or objects other than the established media” (Oxford Dictionaries, 2010), while the noun display is among others defined as “a collection of objects arranged for public viewing”, but also as “an electronic device for the visual presentation of data or images” (Oxford Dictionaries, 2010). Following these definitions the compound term *ambient displays* characterises appliances present in the close proximity of mainly visually solicited receivers. The technical term this review is referring to goes beyond this mere linguistic definition, describing a renunciation of human-computer interaction (HCI) paradigms where information is delivered constantly demanding the focus of attention. Looking beyond this unilateral communication channel Wisneski et al. introduced ambient displays as “new approach to interfacing people with online digital information” (Wisneski, Ishii, Dahley, Gorbet, Brave, Ullmer et al., 1998). Inspired by Weiser’s vision of ubiquitous computing (Weiser, 1993) the “information is moved off the screen into the physical environment, manifesting itself as subtle changes in form, movement, sound, colour, smell, temperature, or light” (Wisneski et al., 1998). Instead of demanding attention the approach exploits the human peripheral perception capabilities.

Following Wisneski’s view (Wisneski et al., 1998) on ambient displays, who basically defines ambient displays as embedded in the environment close to the user and presenting information related to the user’s current context, awareness can be deduced as a main instructional characteristic of ambient displays. To grasp the application possibilities of ambient displays in learning contexts this concept needs to be further exploited, e.g. by accomplishing this perspective with the concept of situational awareness (Endsley, 2000). Endsley defines situational awareness as “the perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future”. Following this definition the author presents three levels of situational

awareness that can be used for classification, namely perception, comprehension, and projection. Perception is related to situational cues and important or needed information, comprehension relates to how people integrate combined pieces of information and evaluate their relevance, and finally projection relates to how people are able to forecast future events and situations as well as their dynamics. Especially on the higher levels of situational awareness the type and characteristic of feedback given by the ambient displays plays an essential role for their effectiveness, impact, and behavioural change capabilities and thus is another important instructional characteristic that can be deduced. In that sense also the concept of providing (instructional) feedback needs to be incorporated, whereas Mory (2004) provided an extensive research review (Mory, 2004).

As mentioned the actual information presented through the display might be delivered addressing the receiver's vision, hearing, haptic, olfaction, or taste utilising ambient information systems. Based on a comparison and discussion of existing ambient information systems by Pousman and Stasko (2006) respective systems can be classified. The four design dimensions information capacity, notification level, representational fidelity, and aesthetic emphasis are thus used within the classification framework to describe the reviewed ambient display prototypes. According to the authors information capacity is determined by the amount of information represented by the system, notification level is the degree of user interruption, representational fidelity describes how the data is encoded, and the last dimension reflects the emphasis put on aesthetics (Pousman & Stasko, 2006).

Analysing and classifying work in the research field of ambient displays with a focus on their use for learning support highlights ambient display characteristics. Across the reviewed articles the individual characterisations of ambient displays are diverse and multifaceted, still mostly building upon the definition by Wisneski et al. (Wisneski et al., 1998). Following this definition under consideration of interactional, instructional, and informational aspects several characteristics can be derived.

Approaching *interactional aspects*, ambient displays are characterised as informative appliances that are embedded into the physical environment (e.g. Brewer, Williams, & Dourish, 2007). Thereby the embedding is supported and fostered by an unobtrusive and peripheral design (e.g. Shen, Moere, Eades, & Hong, 2008). Apart from that ambient displays are characterised as addressing various forms of sensitive perception (e.g. Mankoff et al., 2003).

Regarding the *instructional aspects* of ambient displays the main characteristic described is the utilisation of subtle communication methods mainly out of the

focus of attention (e.g. Stasko et al., 2004). This general characteristic is complemented by several requirements, such as to be glanceable and pre-attentively comprehensible (e.g. Mankoff et al., 2003) as well as not distracting nor demanding attention (e.g. Hazlewood et al., 2008). Another complement is the instructional ability to move from the periphery to the focus of attention and back (e.g. Ferscha, 2007).

Conclusively two characteristics approaching the *informational aspect* can be derived from the reviewed articles. Ambient displays distribute non-critical information (e.g. Bonanni, 2006), although the information is often contextualised and enriches the environment (e.g. Minakuchi et al., 2005), and they establishing informational awareness (e.g. Reitberger et al., 2007). In addition to the presented core characteristics some authors also lay a particular emphasis on aesthetical features and decorativeness. These characteristics complement several interactional and instructional characteristics mentioned above.

3.4 Tangible Objects for Learning

In 2009 smart objects have been named in the Horizon report as one of the relevant technology trends with a time-to-adoption between four to five years (Johnson et al., 2009). In principle the report defines smart objects as “*objects that know about themselves and link the real world with digital information*”. Smart objects in that sense use embedded technology to track state changes in the environment and their context. Relevant technologies are QR codes and barcodes, RFID and NFC technologies, all other kind of embedded sensor technologies that can track changes of objects state as accelerometer, magnetometer, gyroscope, and others. The capacity to integrate smaller and more sophisticated digital technology into physical objects has created a new generation of materials (e.g. *SnapToTrace electronic textile* from Stark (2012) and the *Embedded soft Material Displays* in order to improve and augment tangibles as stated by Manches (2011).

In the research on tangible interfaces different classification systems have been proposed since Ishii (1997) published and defined the term “tangible bits” as “*...an attempt to bridge the gap between cyberspace and the physical environment by making digital information (bits) tangible*”. Based on how tight the mapping between physical representations and digital information is implemented, Project (1998) classified tangible interfaces into indices, icons, and symbols. Holmquist (1999) went further on the nature of this mapping and categorized tangible technologies into containers, tokens and tools. In his distinction, containers are generic objects used to move information between different devices and platforms, tokens are handlers for accessing stored information, tools are used to manipulate

digital information with which they are associated. Furthermore, Holmquist's classification is based on the degree of how well the physical object reflects or enacts the digital information.

Similar Koleva (2003) considered a weak and a strong degree of coherence between the physical and the digital object as relevant. As an example of a high level of coherence, a digital pen could be considered as an object with coherent form, function, and manipulative characteristics in the digital and the physical world. The weakest level of coherence could be represented by a mouse device, as the physical object doesn't enact the actions that can be performed making use of it.

Marshall (2003) suggests two kinds of activity for using tangibles in learning: expressive and exploratory. On one hand, expressive tangibles would be the ones that enable learners to create their own external representations. On the other hand, exploratory tangibles support learners to focus on the way in which the system works, rather than on their own representations.

There is the underlying assumption that using tangibles is beneficial but some authors like Uttal (1997) and DeLoache (2004) have claimed that effectiveness in manipulatives in learning is not consistent. These authors state that the process of associating an abstract idea (e.g. mathematical expression) or a symbolic function to an object is not developed with the same effectiveness depending on the learner.

However, the research in this field has helped to articulate various mechanisms by which tangibles have benefits on learning. Montessori thought "learning is a physical act" and demonstrated that young children are intensely attracted to sensory development apparatus (Montessori, 1917). This phenomenon has been widely studied as embodied cognition based on the idea that the motor system influences our cognition, just as the mind influences bodily actions. Montessori believed that physical engagement can support learning by providing concrete anchors for theoretical concepts. More recent research on tangibles for learning by O'Malley et al. (2005) concluded that physical activity itself helps to build representational mappings that serve to underpin later more symbolically mediated activity after practise and the resulting 'explicitation' of sensorimotor representations.

Moreover, O'Malley enumerated some benefits to take into account: tangibles bring physical activity and active manipulation to forefront of learning, i.e. reduces learner's cognitive load for performing non-content related tasks in order to enable learners to allocate cognitive resources and understanding the educational content of the learning task. Sedig (2001) carried out a study in which he determined that learning with tangibles is not only active learning, it is also important to build in

activities that support children in reflecting. This study examined the role of interface manipulation style on reflective cognition and concept learning.

3.5 Location-based and contextual learning

Based on Brown, E. J. (2010). Education in the wild: contextual and location-based mobile learning in action. A report from the STELLAR Alpine Rendez-Vous workshop series. (E. Brown, Ed.) Garmisch Partenkirchen Germany. Learning Sciences Research Institute, University of Nottingham. Retrieved from [http://www.telearn.org/warehouse/BrownE_SharplesM_2010_\(002715v1\).pdf](http://www.telearn.org/warehouse/BrownE_SharplesM_2010_(002715v1).pdf)

In the first Alpine Rendezvous supported by STELLAR a workshop on Location-based and contextual learning has been organized and the report that consolidates the main research trends and issues has been published and widely cited (Brown, et.al, 2010). The workshop aimed at sharing good practice of research innovations and case studies, engaging in debate and discussion of critical issues surrounding contextual and location-based mobile learning both currently and in the future and to conduct future-scanning activities in contextual and location-based learning.

“The workshop explored recent innovations into location-based, or geospatially-informed, contextual mobile learning, and issues arising from them. Location-based technologies offer opportunities for new forms of learning that engage more deeply with physical surroundings and support continuity of understanding across settings; they also pose technical difficulties of modelling and maintaining continuity of context, and ethical challenges including the right to privacy of location and escape from continual monitoring.”

3.6 Smartphones as generic mobile learning tools

Mobiles as learning technology have surfaced in several of the recent reports and have dramatically evolved in the last ten years. Nowadays, mobile devices can be context-aware of their environment, and already have built-in sensors ranging from location sensors to detailed 3D movement gyroscopes. Flat rates for cheap data access have been established around the world and these devices can be equipped with special software and applications. In that sense, smartphones become more and more universal tools for dedicated purposes and apps even become available cross platform so that the seamless use of services in combination with smartphones becomes more or less a commodity.

For mobile access to information all major Learning Management Systems (LMS) both open source and commercial offer mobile solutions nowadays. While the

functionality of these mobile LMS support varies between support simple updating and news functionality to full fledged access to an LMS.

Mobiles develop towards flexible and multipurpose tools for accessing and connecting information and the real world.

The multipurpose usage of mobile devices can be structured best according to the educational functions these tools support:

- Mobile content and LMS access,
- Personal notification systems,
- Response systems either in Classroom Response Systems or in distributed collaboration systems,
- Data collection tools for documentation of learning experiences.

3.7 Mobile Serious Games

Within the past five years, the number of Mobile Learning Games has snowballed. For commercial and for scientific use they have been developed for various target groups and learning contexts (Lilly and Warnes 2009) such as role-based history learning (Akkerman et al. 2009), interactively discovering the principles of digital economy (Markovic et al. 2007) or geometry (Wijers et al. 2010).

Concurrent to the quickly developing field of digital games, there have been efforts to find a common structure and language for this vast field to better understand the complex issue (Björk and Lundgren 2003; Kiili 2007; Cook 2010). The highly complex technologies and the many different gaming opportunities available make it increasingly difficult for educational practitioners to decide which game to choose for learning.

Games are mostly categorized according to game genres i.e. adventure games, role-playing games, strategy games, or simulations (Prensky 2007). In the context of current game research activities this categorization has proved to be of little use (Gros 2007, Davidson 2004). Especially in the context of educational games the traditional categorisation of games according to genres is not stable and rather difficult to apply. This is due to the vital need for tailoring learning offers (i.e. educational games) according to the learners needs and according to the learning target instead of fixed genre features.

Different educational effects of mobile learning games have been researched mostly in the areas of cognitive and affective learning outcomes.

3.8 Cloud computing for seamless learning support

Cloud computing relieves the end user of thinking about storage and access to data and services. Rao, Sasidhar, and Satyendra Kumar (2010) discuss the following advantages to use cloud computing for mobile learning: costs, flexibility and accessibility. Commercial services today allow one to have personal information distributed, updated, and accessible from a variety of devices. Social web services have driven this for all kinds of media like photos, videos, calendars, documents, or notes.

Cloud computing enables access to all your personal information just with a network connection and synchronised over a variety of mobile and computer terminals.

This trend is clearly linked to the seamless and ubiquitous access to information. Its usage and scenarios in educational scenarios are limited till now. The cloud offers a lot of potential to ensure access to important resources and information like learner profile data (e.g. prior knowledge, preferences), learning resources but also process related information like learning paths or current level for a specific learning goal. In combination with context filters and mobile applications the cloud can become the basis for a mobile personal learning environment (PLE). PLEs are socio-technical frameworks in which learners combine digital resources, information and contacts to monitor, reflect and document learning products and learning processes that can be shared again on the basis of standards.

The cloud unlocks a new potential for the development of seamless learning support that overcomes the existing problems of time and location and allows for a truly ubiquitous learning experience.

4 Stakeholder workshop “Learning in Context 2012”

In March 2012 a workshop in Brussels was organized also to reflect the current trends and collect perspectives on the topic from different stakeholders and researchers in the field (for background information see <http://portal.ou.nl/en/web/topic-mobile-learning/learningincontext2012>).

Basically the workshop was organised to give background and theoretical research works on the topics of contextualisation and context, therefore several leading researcher in the field have been invited to give an introduction to a perspective and important issues about learning in context.

Second several application domains have been presented in the afternoon ranging from logistics, security and defence, eHealth, higher education, and law. Furthermore different specific domains and technologies for learning and cases of using context for learning support have been illustrated, i.e. language learning, augmented reality, and learning analytics.

The second day of the workshop was focused on the stakeholders’ context. Based on the presented visions and experiences of the participating stakeholders, several issues and questions have been discussed guided by the following questions.

1. What are the “Grand Challenges” for learning in context in your educational sector?
2. What are the main barriers and problems to be approached, and what are the research opportunities?
3. What are the steps to reach the vision of learning in context?

The workgroups have been focusing on 5 different sectors and the main results can be seen in Figure 3.

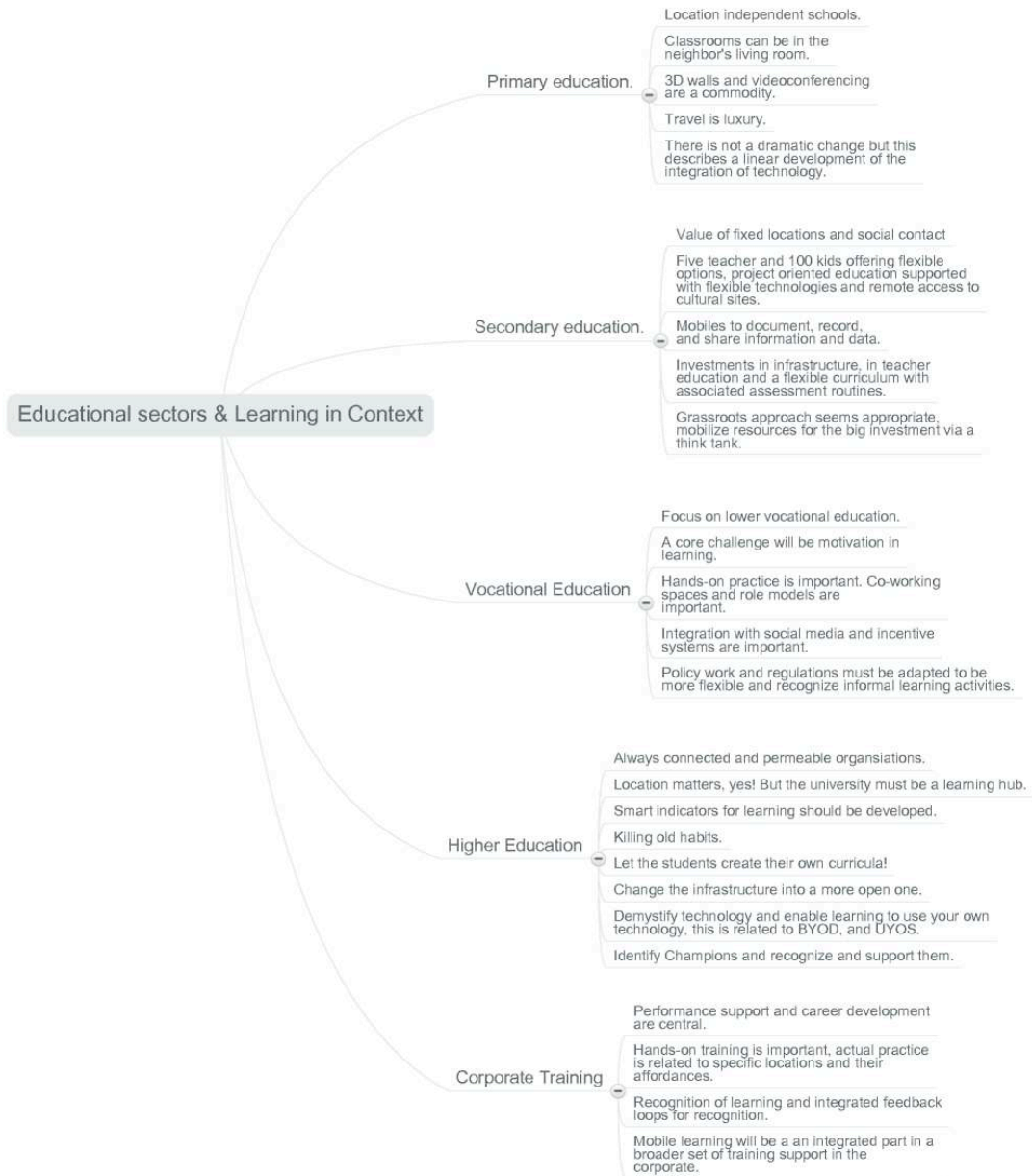


Figure 3: The future vision of different educational sectors for 2017, what is the relevance of mobile and contextual technologies in these, and what needs to be done today.

Overall the participants agreed on an integrated vision of technology and relevance of smart and more contextualised technology that enables also flexible teaching and learning connected to curricular structures. Furthermore the relevance of location as an enabler and authentic hands-on context has been stressed but also the flexibility of accessing and giving support in these locations has been highlighted. Recognition and linking of formal and informal learning experiences and activities has been identified in all groups as a major grand challenge and also

as an opportunity for mobile and contextual learning.

For starting to implement these visions several points have been identified: In most cases thinking out-of-the box, the role of innovation and investments in infrastructure has been noted. Infrastructures should enable the flexible use of technology in permeable organisation and also flexible structures for formal education. On the one hand programs for digital literacy education on the other hand also the freedom to use personal devices and technologies in formal learning contexts has been defined.

Some aspects have been unique to the different educational sectors. For primary education the flexible use of 3D walls, remote access, flexible schooling locations and curricula has been outlined. For secondary education the strong link to practice and specific locations has been stressed. For higher education the flexibility of a support infrastructure and the role for a future university as a learning hub has been defined. For vocational training also the motivational issues have been ranked high and the flexible use of technology in integrated co-working spaces and the potential of linking role models has been highlighted. For corporate training also the link to the workplace practices and the focus on performance support and career development have been identified.

5 Conclusion

This deliverable summarizes some notions, interpretations, design practices and structures discussed and researched around the concept of context in learning and education. It stresses the current trends to research the “re-design of learning contexts” to better understand their impact and create more flexible, adaptive learning spaces, not only in the digital sense, but also in a linked sense between physical and digital world. The results presented in this report come from ongoing research projects, desktop research, as also an expert concept mapping study an expert research workshop and a stakeholder workshop. So it integrates different perspectives from researchers and multiple stakeholder groups.

From all these different perspectives the research issues of ***deepening learning experiences*** through the use of contextual technologies on the one hand, as also the ***use of technology to bridge and connect different learning contexts*** are currently a focus of research.

On the one hand these kind of research activities can be found on the theoretical level as in the Ecology of Resources Framework, but also in the research on specific technologies as tangible objects, augmented reality, sensor technologies, ambient displays, and mobile and contextual learning support.

Certainly these questions can be found back in the results of the workshop with stakeholders organized jointly with the WP5 of STELLAR. In this workshop several issues of place, location, and the contextualisation of learning activities have been discussed and reflected in the workgroups on different educational sectors. What can be seen further from the workshop with stakeholders is that the integration of mobile and contextual technologies in everyday learning activities (formal and informal) must be supported with flexible curricula, flexible instructional designs, and a policy of openness and recognition of learning. The identification of champions and the support of these as also the research on the development of digital literacy and the meaningful adoption of technology seem to be important pillars in paving the way towards an integrated vision of Context and TEL in different educational sectors.

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