Learning in a Technology Enhanced World

Context in Ubiquitous Learning Support

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Inaugural Address

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on Friday, September 11, 2009

by prof. dr. Marcus M. Specht

Chair or the Board,
Dear family, friends and colleagues
Ladies and Gentleman

Technology pervades ever more and ever deeper the very fabric of our Life. Science fiction writers draw a vision of a world enhanced with sensor grids and nano-bots in which we live surrounded by ubiquitous technology embedded in everyday objects. For some of us this vision of the future might be scaring, for others bright. Here I would like to discuss the impact this change has on learning and the research necessary to create the available technological options and choices for supporting learning. This address tries to take a broad perspective on learning in a technology enhanced world and define the road to a better understanding of context in ubiquitous learning support.

On the one hand ubiquitous technology nowadays changes the way we communicate and it enhances our capabilities to connect with others or interact with our augmented environment. These media are by no means neutral, interchangeable instruments that just support human needs, but instead they are assumed to actively enable new modes of human behaviour and human learning: *people change by their tools* (Feenberg, 1991).

On the other hand instructional and learning sciences rarely have had an impact on the design of new technologies. In this address I will describe some evidence that we are in the middle of a qualitative change for the role of technology for learning and that there is an important contribution from the learning sciences to define future technology for learning.
A key claim is that technological innovation and educational paradigms have to develop side-by-side, connecting technology innovation, educational models, and theories for contextual learning.

A key question in this work is: how can we unleash the power of contextual effects when we design ubiquitous learning support?

In the following sections I will first outline what the current developments and trends in technology for the next five to ten years are and what their potential for enhancing learning is.

Second, I will describe how these developments and innovations already today influence the way we communicate, live, and learn. How the generation gap between digital natives and digital immigrants is leading to different perceptions of digital media and their use for learning and teaching.

Third, I will outline some research on context and learning. I will describe examples of what I mean when I talk about context and I will give an overview of the usage of context in education and the key effects we can expect from contextualising technology enhancements for learning. What are the variables and design parameters we have to consider when we design contextualized learning in a technology enhanced world?

In the fourth part I will introduce the model of ambient information channels that is a structuring metaphor for contextual learning technology.

Last, I will highlight some key questions for a future research agenda in the field of contextual learning support and describe some research we are currently working on at the Centre of Learning Sciences and Technologies (CELSTEC) here at the Open University of the Netherlands.

A Technology Enhanced World

Human enhancement refers to any attempt to temporarily or permanently overcome the current limitations of the human body through natural or artificial means (Wikipedia, 2009).

Technology enhanced learning in this sense refers to the enhancement of learning support via information and communication technology.

Enhancing the human capabilities to work with information is a key concept that is already embodied in very old tools as paper and pencil. Paper and pencil enable humans to make information persistent, to illustrate, to annotate, to distribute and much more.

A blackboard is an example of a specialized device that is optimized for classical lecture room scenarios, in which a teacher illustrates concepts taught in the lecture. The blackboard concept has been developed further in the last years towards interactive boards. Whilst these interactive boards would allow for the use of all kinds of digital media in the classroom in most cases the boards are just used as writing tools and even more in most cases students are more fluent in interacting with the boards than their teachers. This is a classical example of a technology development where the educational setting is not adapted to unleash the potential of a technology for best learning support. The underlying dilemma of course is that in designing new technology for education most proposed solutions are driven by hyped technologies or existing practices. Probably we need to extend our approach a bit more towards a vision of magic enhanced learning.

Some of you might have watched the movie in which Harry Potter makes use of a magical "Marauders Map" of Hogwarts Castle. On this map you can see everybody in the Castle moving and therefore observe others or avoid being detected. This kind of magic is something that is not magic anymore today; this can be achieved with solidly engineered technology. From a broader and more futuristic perspective you might also consider technology-enhanced learning as *magic enhanced learning*. When thinking about the future of learning we therefore should probably not limit ourselves to the technology we know today but think about magic in some parts of the envisioned solutions. Let us assume technology will create the magic parts.

The example takes on several important developments in technology with which we can already enhance learning experiences today. In the Open University of the Netherlands we are using this kind of tracking technology to give guided tours through the Media Laboratory. The main difference is that a person needs to wear a little badge that allows a computer system to track him or her. This tracking allows for all sorts of learning extensions one can think of. In a room a voice can start to talk to you dependent on what you look at. Technical documentation could make use of this to provide you the information needed at your current location and working situation.

In general there are several high level technologies that can be identified as relevant for learning. In its yearly reports the Horizon Project analyses and describes main technology trends and their impact on teaching, learning, research, or creative expression. 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.

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, or already have built-in sensors to read Radio Frequency tags. Flat rates for cheap data access have been established around the world and these devices can be equipped with special software and applications. As an example the Apple Application store holds around 65.000 specialised applications that can be installed on a mobile phone. *Mobiles develop towards flexible and multipurpose tools for accessing and connecting information and the real world.*

Cloud computing relieves the end user of thinking about storage and access to data and services. Commercial services today allow you 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 gives you access to all your personal information just with a network connection and synchronised over a variety of mobile and computer terminals.*

Geo-Everything allows everyday users to save location information with almost every kind of media they produce. Applications today already automatically add data about the location where you have taken photos, videos, or audio recordings. First applications in education have explored this in the area of educational field trips but as new developments on mobile augmented reality demonstrate there is still a lot to come from geo-tagged media. *In general all kinds of context metadata will enable new ways of filtering and interacting with content in context.*

The personal web is also a topic that reoccurred in the last years. Before cloud computing and well usable mobile devices it was still very difficult for the average computer user to build personal websites with media today this is easy. Everyday users can create personal web blogs, photo galleries, video channels, or audio stations, just by adding files from a local recording device within a minute. *The creation of media for the personal web will be pushed via mobile content creation and this will make mobiles more interactive and personal tools.*

Smart-Objects are connected to the topic of Internet of Things. Today we are rapidly moving towards an Internet of Things where not only digital information is stored on the web, but also physical world objects enriched with sensors become aware of their environment. Connecting information and learning services to artefacts will be a next logical step when implementing ubiquitous learning support. *Designers will embed interaction facilities into everyday objects, which will be intuitive to use while still augmented.*

Most of these technologies interconnect the real world and the information world. I consider this relation as a core for contextualised learning support (Gross & Specht, 2001).

In that sense the connection between digital and physical objects builds a new landscape for learning of the future.

So in the following section let us consider how the data and information on the World Wide Web - as the most prominent and widely used Internet system - has changed in the last years.

The Enhanced World Wide Web

There has been an enormous growth of the worldwide web since Sir Tim Berners-Lee built his first website in 1991. The available information is growing unbelievably fast and so is the number of users. While in 1997 about 10 percent of inhabitants of "developed countries" where using the Internet regularly, these where already 62 percent in 2007 (Internet world Statistics, 2007).

Furthermore in the last years we are changing from passive information consumers to information producers and consumers - we become "prosumers" of social content. According to Internet traffic studies in 2008 already five social web services where amongst the most used services on the Web, while in 2005 this was just one (Alexa, 2009).

These social web services have enhanced the way a broad public can handle and enrich web information. Even just by using the WWW we leave traces and "create" social metadata. Users create more and more data about data (metadata). All kinds of annotations, classifications, discussions, usage information, and references are added on top of the information as such. This metadata can be used to enable users to find all kinds of new media for instruction and learning even from mobile terminals.

As an example of a powerful mobile application today you can speak some words into your mobile phone and a voice search application will give you the search results. This example includes several highly developed technologies, which are integrated as speech-to-text recognition, advanced search and indexing methods, location tracking, and others. Nevertheless, the example hides the complexity behind a very intuitive and simple user interface.

Besides social content and metadata more and more *rich content* is becoming available and produced by prosumers. Nowadays video recording, audio recording, and even video game creation are intuitive and can be done by most of us. In the last year two major game titles have been released that shifted the focus of the game from being a game player towards being game level creator and share the creations with others. In these games end users can design game characters as in SPORE (Wright, 2007) or design complete game levels as in little Big Planet (Little Big Planet, 2008).

As a core conclusion: *we are prosumers of the social web enriched with contextual metadata. This metadata is the key for linking of web information with the real world*.

So what is about educational content?

Enriched Open Educational Content

Imagine the last educational book you have read. Decompose it into all its Explanatory paragraphs, examples, definitions, illustrations, and parts, as you like. These components or "assets" as they are called in the learning objects world can easily be converted and delivered into different digital formats. You could also easily aggregate them into a different sequence or link them in a hypertext structure that would enable you to explore the book in your personal way. You could only look at all examples and try to understand them; you could use the definitions in drill and practice exercises or at home on your gaming console in a quiz. If you are an advanced learner in the domain you could use it as a reference book or even to teach some colleagues by re-aggregating the components in the way that you can best make sense out of them.

As described in the example learning content can be decomposed and recomposed with new technologies. Nevertheless the sense-making and the individual experience is driven by a perspective, a context in which you put yourself while using the content. You can imagine that there is a tension in the opposite direction between the granularity of decomposition and the educational context.

It is as with a puzzle game for which you do not know the whole picture. The more pieces you have the more complicated it is to get the big picture.

To store the educational context of learning objects metadata is often used. While ten years ago metadata was mainly used to describe an educational object, today metadata is much more about the meaning and sense-making process in learning. *Metadata in this sense is closely related to core processes of learning as reflection, guidance, and feedback*.

An important development of the last years has been the creation of learning object repositories and their federation. Today we have big international initiatives as GLOBE (Globe Consortium, 2009) and standards, which enable learners to search worldwide for learning content. In the Open University of the Netherlands we are involved in several European initiatives for new forms of metadata use in teacher education, architecture studies, or management education.

To achieve personalized and contextualised learning the flexible de- and re-contextualisation of learning content is essential. The reuse of learning content is building on new technologies of content federation and publishing.

Also this content is in many cases already accessible via mobile devices, so what are the consequences of this?

Mobile Access to Information

"The explosion in the number of mobile phones with the capacity to access the Internet will enable millions of people in developing nations who cannot afford computers to go online for the first time." (Berners-Lee, 2009)

Around July 2009 more than 50% of the world's population owned a cell phone while in 2000 these were just 12%. Each year nowadays more than 1 billion mobile phones are sold: in 2008 it were more than 1.2 billion. In general I would like to mention four trends, which can be identified in association with the fast development and deployment of mobile phone technology on a global level:

a) *Information can be accessed not only in city centres but much more important in rural areas*. Especially in remote areas this will have an immediate impact on business processes, life-long learning, and everyday living. Examples are health education on HIV, information about food distribution, social support against discrimination, election monitoring by instant messaging, collective news reporting, finding jobs through SMS marketplaces, or accessing market prices for goods (Mobile Active Consortium, 2009).

b) *The available information will grow even more rapidly as more people will have access to it and generate metadata and data*. Mobile devices combine properties of other media as text, voice, audio, and video with geo-location and they are affordable to low and middle level income citizens. This basically means that with low cost end user devices information can be easily collected and distributed based on existing networking infrastructures.

c) *Mobile devices will make intensive use of sensor technology and therefore become more context-aware*. The information received and created on mobile devices can be analysed in the context of this sensor data. This issue is highly related to current discussions on privacy of information and tracking of users in real world and information space.

d) *New user interfaces will synchronise multiple information channels available on infrastructural and mobile terminals*. A desktop metaphor does not hold for a mobile information access in which we move away from our physical desktop. Steven Feiner already in 1999 describes the relevant issues in user interface design when we work and live in an environment where several displays can be used for personal and shared information (Feiner, 1999). Sensor-based user interfaces will lead to a complete redesign of the user interface in the next decade.

In a recent report about the use of mobile phones in citizen media the technological features of mobile phones and their potential for consuming and producing mobile social content have been analysed (Mobile Active Consortium, 2008). The key features identified are:

Text messaging holds the potential of instant exchange and update of personal information channels. The underlying model allows new information distribution models like personalized information channels or micro-blogging. Furthermore, nearly every mobile phone used today has SMS messaging capabilities. Successful services are released all over the world with a focus on India, South America, and Africa.

Voice and Audio: mobile phones can do much more than just enabling direct phone calls to another person. You can connect to several persons in an audio conference, you can call in to service for recording and instant publishing of a phone call, you can use voice-based services to navigate in applications, or you can connect to online audio streams or FM Radio networks.

Photos and Videos allow mobile phones to create low-fi content on the spot and distribute contextualized information. A prominent example is the recent release of the iPhone 3GS, which can record videos and submit them to YouTube mobile. In the first 5 days after the release of the device the mobile content uploads to YouTube grew by 40%.

The affordability, computational power, and scalability of mobile devices will basically result in a skipping of the desktop computer generation in development countries. So this will make mobiles universal tools for reading, discussion, documentation, annotation, and others learning activities. So what is a new vision on personalisation coming out of that?

What makes Learning Personal?

The personalization of learning experiences has been researched in instructional psychology since the 1950s. There is a variety of ways in which the selection and the presentation of learning content has been personalized in the past. Personalization in this sense has proven to be able to gain more efficient and effective learning support for different learning objectives in a variety of educational settings.

In the last years my interpretation of what makes learning personal has developed away from the traditional course of optimizing algorithms for most efficient sequencing through a curriculum. Personalization has two sides that in my view have high relevance for learning. On the one hand *the reflection about the self in a social context*, on the other hand *the creation of something personal* by using and learning with it.

All of us know the second notion, for example, when making annotations to a book while reading. Annotations make the book unique in which the reflection and learning is documented. When we talk about personal things we think about something that has meaning for us, this includes cognition, emotion, and motivation.

In this sense the social personal web enables sense-making with personal interfaces that can make use of the huge body of information described before. The right combination of content resources, services to personalize them, and the social context is an important research question in the area of Personal Learning Environments and Mash-Ups for Learning.

How do we personalise and contextualize media, services, and users so that these make sense to us?

Nowadays the creation of personal media is probably most powerfully implemented in computer games. More and more of new video game titles also combine virtuality and reality and use the real world as their playground.

Games bridging Virtuality and Reality

Game-based learning is strongly associated with engaging learners where they directly learn from the invoked responses of the gaming environment. Educational games have been researched coming from different theoretical backgrounds as experiential learning theory (Kolb, 1984), problem solving (Savery & Duffy, 1995), learning by doing (Schank et al., 1999) or self-regulated learning (Zimmerman, 1990).

A core component of the engaging and efficient learning in games is the instant feedback in these rich and interactive environments. In a real-time gaming environment each action of the player may trigger instant feedback and subsequent reflective thought processes.
The engagement and positive affect are beneficial in self-directed learning scenarios, where learning success is related to a lasting self-motivation of the learner (Pintrich, 1999). Games often make implicit use of highly efficient adaptation algorithms that focus completely on the gamers'

motivation to continue playing the game in the emotional state of "flow" (Johnson & Wiles, 2003).

Most commercial games today are happening in virtual reality but more and more games take the real world as the playground. Combining game logic and real world affordances will be a powerful approach in the next years for serious gaming. By embedding information displays into the physical environment the learner has the opportunity to take many factors of the real world's fuzziness into account (Klopfer, 2008). In a mixed reality environment learners have the possibility to apply knowledge right in the middle of unpredictable real life. According to Milgram and Kishino (1994) mixed reality can be defined as a continuum between virtuality and reality.

This continuum enables two options when designing learning environments. On the one hand instructional designers can use simplifications of complex real world environments to enable learning in virtual gaming worlds. On the other hand real world environments can be enhanced with educational artefacts. Both approaches can work hand in hand and synchronization between virtual and real world spaces can facilitate cooperation between learners.

Computer games will play a key role in mixed reality applications for learning as they combine personal creation of artefacts and adaptive game patterns for engagement.

Personal Learning Everyware

In his book “Everyware” Adam Greenfield discusses the implications of ubiquitous computing becoming integrated in our daily life and everyday objects. Greenfield describes Everyware as information processing embedded in the objects and surfaces of everyday life (Greenfield, 2006). He is considering ubiquitous technology on different scales.

On the scale of a body network sensors will enable you monitoring your body functions and get instant feedback on your current status. As an applied example with intelligent clothing for doing sports you will be able to optimize your practicing with direct feedback on your movements, running speed, breathing, and other body functions. E-Health is already now a big application area of remote accessible body sensors.

On the scale of a room intelligent carpets, wall colour, or gesture tracking installation will support you with interaction facilities needed for your current task or support your current informal learning activities. Let us assume a room you enter could identify that you are currently learning French and would give you the main objects of this room labelled in French.

On the scale of a building, architects already create completely new facades for buildings. Efforts as ArchiOS as an integrated Operating system for buildings interweave all activities around facility management and human activities related to a building. This interconnects cross-room learning activities, necessary resources, and support facilities.

On the level of public places and city planning new artefacts will enable dynamic routing and highlighting of space related information. Enabling the exploration of augmented everyday objects in informal learning situations.

The integration of computers, sensors, and displays in everyday objects as clothing, furniture, walls, doorways, cups, or kitchen makes it important to understand how learners make use of mobile devices and artefacts in context.

The Technology Enhanced Learner

The future is already here it is just unevenly distributed. (William Gibson)

As we have heard in the last part: we have more rich data, more tools, and new forms to interact with computers. Several studies show that this is apparent in all parts of society and that there are several trends in the usage of these technologies.

One the one hand the average age of mobile phone and Internet users gets lower every year and additionally around 50% of the world population have mobile phones. On the other hand in relational terms the most significantly growing age group considering Internet usage between 2000 and 2008 was the age group between 60-64 years. While on the whole population between 2000 and 2008 availability of a mobile phone was raising from 46% to 91% in the age group between 60 and 64 is was raising from 20%-72% (ACTA, 2008). These numbers demonstrate a broad adoption of these new technologies in all age groups of society.

Nevertheless, considering the development of technology and the way people have used this technology in the last twenty years there is also a generation divide between the digital natives and digital immigrants often cited in the literature. A recent study from the United Kingdom analyses the differences especially considering their potential for learning (Green & Hannon, 2007).

In general there is a broad adoption of mobile and new media technologies in nowadays society. Let us do a small mind experiment now:

Imagine your life without a mobile telephone and without the Internet.
SO … No mobile phones, no Internet! Think about it.

How would this change your daily living and learning? How would this change the next activity you are planning to do when walking out of this room? How would this change the ways you carry out your tasks at work or in school? How would this change your leisure time activities?

New tools new learning?

That the use of digital media by the younger generation changes dramatically has been studied since several years (Medienpädagogischer Forschungsverbund Südwest, 2009). Today the younger generation uses more Personal Computers than TV systems (Allensbacher Computer- und Technik-Analyse, 2008). In the last 5 years Web 2.0 changed the daily live of school children, higher education students, researchers, and lifelong learners. In 2008 the German newspaper "Die Zeit" published a series of articles describing how teenagers today live in a world of social networking in which you have to be careful about your online profile and what others publish about you.

Digital natives today use social networks for all kinds of communication about homework, dating, and leisure time. But it is also a dangerous world of cyberbullying, cybermobbing, and cyberstalking which according to recent analyses are amongst the biggest threats for digital natives (Davenport, 2008).

Analysing the use of Web 2.0 the "Their Space" study has found that one core difference of digital natives seems to be a different estimation of the importance and usefulness of new media for learning. The study identified different types of young users as digital pioneers, creative producers, everyday communicators, or information gatherers (Green & Hannon, 2008).

Additionally, in the classical learning settings as school and higher education we can observe a change in the type of tools used by the learners and educators. Every year the Centre for Learning & Performance Technologies invites experts around the world to select their top 10 tools for learning. Looking at the tools currently ranked in 2009 only one kind of traditional classroom technology (i.e. Powerpoint) is in the top 10. All other services and tools are social software tools, web 2.0 services, instant messaging, and voice-over-IP tools (Tools for Learning, 2009). In that sense social software tools seem to undermine the classical setup of schools, universities and workplace learning. Learners organise and participate in informal learning processes beside the formal instruction received in these organisations.

In many cases mobile phones are still banned from formal instructional settings and seen as a disturbing factor, although they play a highly important role in the informal learning activities of digital natives. Furthermore already in 2002 Tatar et al. (2002) describe a variety of practices in the classrooms where about 70% of the teachers explicitly stated the usefulness of mobile devices.

Today it still seems that mobile devices become more and more accepted outside the classroom and in informal learning settings. They are still considered as a toy or a non-learning device in the classroom.

Importance of Informal Learning

Informal learning takes place outside educational establishments; it does not follow a specified curriculum but rather originates accidentally, sporadically, in association with certain occasions.

Learning with mobiles is interwoven with everyday life and often a parallel activity, triggered by a changing context. Mobile media today enable us to access information and learning support much more spontaneously in a broad spectrum of learning situations and driven by an instant need for information. In that sense it is a key question for mobile media how this use of mobile informal learning tools has an impact on changing our understanding of learning and therefore a restructuring of classical educational settings.

In a study from 2009 (Clough et al., 2009) expert users of mobile technology demonstrated and confirmed a broad range of informal learning activities for which they customize and use their mobile phones. These include collaborative applications, location aware services, data collection applications, referential applications, and others. Several patterns have been identified which interlink the learning activities with daily activities embedded and triggered by contextual changes.

Simply speaking: *Being mobile and moving between contexts actually triggers the need for mobile learning support. On the one hand in different contexts we are confronted with varying clues and the resulting learning needs. We also continue parallel longer term learning activities across different contexts and therefore develop different perspectives on a topic.*

In that sense the first adoption of mobile technology in an informal learning setting seems logical, while the usage of mobile technology in the classroom often still appears clumsy and unnecessary.

More Authentic Learning Support

In the last years a wide range of research projects and school initiatives have researched technology supported field trips. Field trips have been a well established educational method in which mobile media enable the support for distributed collaborative work on learning tasks, documentation of learning experiences from different perspectives, or communication in authentic learning situations.

Situated and authentic learning are described as powerful mechanisms to connect learning and experience, strengthening and enhancing both.

Situated learning for example stresses the importance of knowledge acquisition in a social or cultural context and the integration in a community of practice (Lave & Wenger, 1991). Learning is not only pre-planned by the curriculum, but also occurs through interaction from the learners in their social environment when carrying out tasks in authentic learning contexts.

In the RAFT project live videoconferences have been used to establish a video link between an expert interview in the field and a classroom from which learners could ask questions. As one important finding not only the participants in the field trip profit from the excursion but more importantly students in the classroom develop a more realistic interpretation of application contexts, are more interested in the topic in general, and gender differences in the use of new technology can be reduced (Bergin et Al., 2004, Specht, 2006).

On the one hand the authentic learning support enables the learner to have access to necessary information tools and support in a rich environment offering a variety of affordances and clues for exploration of a topic. On the other hand contextualised support can also help learners to direct the attention in a rich situation to a specific focus or perspective on a topic. In the following part I would like to look at some features of mobile support and its unique possibilities.

Why Mobile Learning?

In principle mobile devices as such have some distinct advantages for learning support (Koole, 2009). Mobile learning enables knowledge building by learners in different contexts, it enables learners to actively construct understandings ('what'), and the mobility often changes common patterns of learning/work activity ('relationships'). Some distinct features and their consequences are:

Always On

They provide access to information where and when it is needed (anywhere, anytime). Mobile learners can travel to unique locations, physically with or virtually through their mobile devices. As stated previously moving between different contexts in that sense triggers new learning needs and those needs can be instantly followed up, which also has a variety of consequences on motivational issues and cross topic transfer.

Authentic Environment, Less Computer

Anywhere, anytime access can provide multiple cues for comprehension and retention. The richness of authentic situations gives a variety of triggers for different learning needs. These learning needs can either be instantly followed up with the help of mobile technology or in direct conversation with peers. Mobile and ubiquitous technology gets more and more invisible and learning by communication, reflection, and inquiry becomes more important.

Concepts are situated

Contexts can provide authentic cultural and environmental cues for understanding, which may enhance encoding and recall. Within the paradigm of situated learning, the specific learning situation plays a key role during the knowledge construction process. During a situated learning setting, the mental representation of a concept occurs not in an abstract or isolated form. In connection with a specific situation, concepts can be instantiated and become concrete.

Personalized and Contextualised Filtering

Contextual information filtering can assist in the reduction of cognitive load by filtering available information based on context as well as the personal history. Different patterns of presentation can potentially help learners to retain, retrieve, and transfer information when needed.

The Mobile Learning is in control

As Sharples et al. highlight; "Mobile Learning is about the mobility of the learner" and in that sense effective learning asks for (a) Construction, (b) Conversation, and (c) Control (the 3 'C'-s). Successful learning is a constructive process that involves seeking solutions to problems and relating experiences to existing knowledge (Sharples, Taylor & Vavoula, 2006). Learning is most successful when we are in control, carrying out an active and continuing cycle of experimentation and reflection (Kolb, 1984).

Sensors and displays, and mobile devices play an important role in designing this continuous cycle of experimentation and reflection, so later I will outline the role of new forms of sensors and displays for learning.

The Core: Context and Learning

In the previous sections I have talked about a technology enhanced world and how learners today use technology enhancements in a variety of learning situations. At the core of understanding why these technology enhancements work is the relation between context and learning.

Contextualised learning support aims to embed the technology enhancements in the natural environment in which learning takes place. It enriches the learning experience by contextualising the human computer interaction, interweaving learning activities and feedback processes, and synchronizing the learner's context and the available information channels and context metadata.

Below I will give a brief overview of research on context and how this is related to learning.

Context gives meaning

The term context is used in different research disciplines. Linguistics makes two claims about context.

Context (plural contexts) is defined as

1. the text in which a word or passage appears and which helps ascertain its meaning.
2. the surroundings, circumstances, environment, background or settings which determine, specify, or clarify the meaning of an event.

Leech (1981) highlights the importance of the context to narrow down the communicative possibilities of a message in several ways. The context can be used for the elimination of ambiguity, the clarification of referents, supplying of additional information, the interpretation of tense, and determination of the scope of quantifiers. All this helps to ascertain the intended meaning of a word or event.

In Natural Language Processing the establishment of the relevant context is a long discussed problem and the determination of the relevant parts or components of a context have been highlighted by Pinkal in Asher and Simpson (1994) as follows:

"Aside from the surrounding deictic coordinates, aside from the immediate linguistic co-text and accompanying gestural expressions at closer view, the following determinants can influence the attribution of sense: the entire frame of interaction, the individual biography of the participants, the physical environments, the social embedding, the cultural and historical background, and - in addition to all of these - facts and dates no matter how far removed in dimensions of time and space. Roughly speaking, "context" can be the world in relation to an utterance act."

The field of context-aware computing has developed a variety of context definitions mostly starting from location or object context. Zimmermann et al. (2007) give a pragmatic definition of context. Following their approach the context of a person or an object can be defined by five distinct parts.

- identity context, this 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 context ranges from simple points in time to ranges, intervals and a complete history of entities.
- location context is divided into quantitative an qualitative location models, which allow to work with absolute and relative positions.
- activity context reflects the entities goals, tasks and actions.
- relations context captures the relation an entity has established to other entities, and describes social, functional and compositional relationships.

In the following sections I will use these five generic parts of context and their subparts as a working definition.

Context-aware ubiquitous computing

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.

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.

In the last 50 years the relation between available computing devices and humans using those devices has basically 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. 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.

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.

One very important issue is to better understand the way humans interact with sensor-based context-aware artefacts as this also holds high importance for supporting learning with such.

Context and episodic memory

Thomson and Tulving (1970) demonstrated the power of the context in encoding information in an experiment in 1970. In the experiment two different groups of participants had to learn a list of words. While one group learned these words on the beach the other group learned them while diving with equipment under water. After the learning phase the participants had to recall the words. One of the results was, that the persons that learned the words under water also where better recalling the words under water and vice versa. This led to the concept of encoding specificity. The theory of encoding specificity states that the most effective retrieval cues are those that were stored along with the memory of the experience itself.

The information encoded while learning in that sense is combined with contextual information about the situation in which it is learned and of course the access of information is also affected by the context in which the information is recalled.

How media can assist in connecting real world experiences and episodic memory has been studied in the SenseCam project by Microsoft research. SenseCam is a wearable digital camera with a fish eye lens that takes images whenever a change in temperature, movement, or lighting is detected. All pictures can be lined up to reconstruct a kind of movie of the day. With a periodic review of these images of events recorded by SenseCam amnesia patients had a significant increase in recall of those events (Hodges et al., 2006).

Also in learning support episodic memory has proven to be a powerful concept to access individual learning episodes and use them in tutoring systems (Weber, 1996). Learners use the information available in the context of a problem and this helps them to retrieve information and relevant solutions from earlier episodes for a current problem. In evaluations of the Episodic Learner Model examples from individual episodes have been shown to be more powerful feedback then expert solutions not used in the own learning history.

Synchronizing learning activities with the physical environment in that sense can be concluded as a promising approach from various theories of learning and cognition. According to information processing theory (Miller, 1956) and cognitive load theory (Sweller, 1988), human working memory has limited capacity and learning content should be structured in a way such that the information load does not overwhelm the learner. Furthermore, multimedia learning theory (Moreno, 2001; Moreno & Mayer, 2000) states that each sensory channel (visual and auditory) has limited processing capacity and learning is optimal when the information presented on one sensory channel augments that presented on the other. On the one hand, the limited processing capacity means the information delivered to the learner should be limited to the information relevant in the current learning context. On the other hand the complementary distribution of information across different channels must be provided.

Lave & Wenger (1991) state that knowledge needs to be presented in a realistic context that would normally involve the application of that knowledge. An authentic learning environment often provides a variability in stimuli, or multiple perspectives on the theory learnt, and needs context-dependent, highly interconnected knowledge; several aspects that are emphasised by cognitive flexibility theory as important for learning. Especially, the variability in stimuli and learning tasks available in an authentic context may result in a better generalisation of the knowledge constructed by learner (Kester et al., 2006).

There is a close connection between the context and the content and learning processes as such and there are powerful mechanisms enabling humans to use contextual information for learning.

Context indicators and feedback

In the Open University of the Netherlands we have recently been exploring the area of context indicators and how context information can support learning in informal and formal learning processes. Our approach makes use of a new way of using contextual information. The main idea is to use contextual information for giving direct feedback to learners and not for inference in an adaptive engine.

Enabling the learner to reflect about his/her own learning process is at the core of Donald Schön's (1983, 1987) concepts of reflection in action and reflection about action. By reflection about one's own learning process, learners gain meta-cognitive competences for steering their own learning and develop awareness about their own learning in comparison to others or to pre-given yardsticks in an instructional design.

In our research we have looked at the effects of sensor information about activities a learner has carried out in different contextual frames. Giving information about how many pages a learner has visited in an electronic system compared to very successful peers has a different effect than giving the same information compared to the average number of activities from the last week. When aggregating and visualising sensor information with different contextual frames, in online experiments effects have been demonstrated on the learner's meta cognition as social awareness, conceptual relations of the subject matter, and process awareness have been demonstrated. Additionally, also varying effects have been demonstrated depending on the personal context and the level of participation in a learning community (Glahn, 2009).

According to Glahn (2009) the *perspective on aggregated sensor data* and the *contrast against which the data is presented* are two essential design parameters for context indicators.

We currently do research to better understand what effects the different variations of contrast and perspective have in the learning-interaction cycle. We explore this approach in personal learning environments, augmented reality applications, and rich metadata environments for learning.

Context, sensors, and displays

As described in the first part, 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. I want to highlight some potential of using sensors and new forms of displays in technology enhanced learning. Sensors can enhance the way of assessment on several dimensions:

a) Multi-method assessment will become much easier as more parts of the assessment process can be supported with measurements of user behaviour in the real world or data that was very difficult to collect before. Simple examples of this trend can be eye-tracking methodologies embedded in real world tasks, or audio annotations while performing real world tasks.

b) Long-term assessment can be embedded in real world learning and performance situations, but also the assessment periods can be prolonged and data can be collected on much longer time periods. Learners could automatically create logbooks of their activities or collect the results in portfolios. Recordings of real time video, audio, environmental data or even biometric measurements can be collected and combined in assessment and feedback.

These aspects are currently reflected in an ongoing discussion about the changing role of assessment from a more formal assessment of a learning outcome to an instant formative assessment helping the learner in the process to understand his/her learning.

Imagine a ball that would be full of sensors that can measure the ball's speed, the pressure applied, direction of movement, and absolute location in a room. All this data would be visualised on a big screen and learners could just play with the ball and observe the sensor data in small experiments, i.e. dropping the ball and learning about gravity, throwing the ball to each other and learning about the distance between each other, bouncing the ball and learning about the optimal pressure to apply for best bounces.

So several parts of the ball example are relevant for learning in a variety of domains as physics, mathematics, sports, music, arts - lots of these kind of examples could be made up. For interacting with real world objects there are several key principles in the ball example, which are essential for sensor-based learning support.

a) Sensor information can give feedback to users about their interaction with objects and enable much more intuitive forms of interacting with real world objects and there augmentations. Furthermore, it can directly enhance real world objects with related information or learning tasks.
b) Sensor information can make abstract concepts visible. In the example the speed of the ball could be visualised in a graph on a screen so learners could intuitively explore the concepts of force, mass, and acceleration and how gravity affects this.

A display can be a screen of your personal computer or a big screen in a public place like in a train station. An auditory display can also be the loudspeaker of your mobile telephone or a full 7.1 sound system in a cinema. Also the force feedback of your gaming console is a kind of display, which can be used to notify you of some event or relevant information. More and more displays are introduced in our world and many of these displays become synchronised with each other. Displays have an important role in learning and enabling learning in several ways:

a) Embedded displays can support reflection in action and reflection about action. According to Schön's approach stimulating reflection processes is essential for learning (Schön, 1983).

b) Multi-modal displays can bring information to the user anywhere, and anytime. Multimodal displays can be used for notification and awareness in individual and group situations.

c) Personal displays and public displays can be used for different tasks in an instructional design. Shared displays can enable awareness and collaboration in learning activities.

Displays and sensors are key components of ubiquitous learning support. In the following section I will integrate all the presented pieces in an integrated model and describe the core processes relevant for learning support.

Ambient Information Channels

In this chapter I will introduce a model for

Ambient **I**nformation **CH**ann**E**ls (AICHE).

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

AICHE gives a simple metaphor of information channels that are ambient all around us. So let us assume it is simply possible to access any kind of information or computational service out of the air (like magic). 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. As outlined in the first two chapters this scenario seems realistic given the current developments of ubiquitous and context-aware technology and cloud computing. The channels coming out of the air can transport multimodal information when bound to displays as visual, auditory, or haptic, gustatory, or olfactory.

All channels have a set of meta-information connected to them as soon as they are instantiated. Basically this meta-information holds all contextual information about a channel like location, id or 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. So what is hardwired today – as for example the fact that you watch your TV channels on your TV – will be flexible tomorrow.

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. AICHE processes

like aggregation, enrichment, synchronisation, and framing describe a contextual learning pattern as in the given example.

In the following sections I will first outline the background and development that led to the AICHE model and secondly describe the components and processes in the model.

Towards an abstracted model

About ten years ago I wrote a paper with my former colleague Tom Gross. In this paper we described a basic model for context-awareness of mobile users. The approach was based on objects in the real world and objects in the electronic world. All objects (virtual and real) could have sensors connected and the information from those sensors could be utilised for creating awareness about users and objects in the vicinity or related objects in the complementary space (virtual or real) (Gross & Specht, 2001).

Since 2003 we have been working on models of content engineering and context metadata. We have developed a model for the engineering of context-aware systems that embedded the different components as sensors, artefacts, and electronic objects in a layered model. In this model we first described the interaction and core processes as aggregation and enrichment (Zimmermann et al., 2005).

In 2005 I started to work at the Open University of the Netherlands and I extended the approach of the layered model by using instructional design models and related standard representations as IMS-LD to specify the logic of contextual learning systems. Furthermore we researched the use of mobile technology and context information for the professional competence development in learning networks.

In an effort to better understand the state of the art and focus of current applications, in 2007 we undertook a literature analysis of mobile social software for learning. Out of this analysis a reference model was developed that allows to describe existing and future solutions on five dimensions (De Jong et al., 2008).

Table 1: Reference Model for Mobile Social Software

CONTENT	CONTEXT	INFORMATION FLOW	PURPOSE	PEDAGOGICAL MODEL
ANNOTATIONS DOCUMENTS MESSAGES NOTIFICATIONS	INDIVIDUALITY CONTEXT TIME CONTEXT LOCATIONS CONTEXT ENVIRONMENT OR ACTIVITY CONTEXT RELATIONS CONTEXT	ONE-TO-ONE ONE-TO-MANY MANY-TO-ONE MANY-TO-MANY	SHARING CONTENT AND KNOWLEDGE FACILITATE DISCUSSION AND BRAINSTORMING SOCIAL AWARENESS GUIDE COMMUNICATION ENGAGEMENT AND IMMERSION	BEHAVIOURIST COGNITIVE CONSTRUCTIVIST SOCIAL CONSTRUCTIVIST

Today I want to present an integration of this work in the AICHE model, which describes the components as sensors, artefacts, channels, and the processes of aggregation, enrichment, synchronisation, and framing.

AICHE structure

The description of contextual learning applications in AICHE works on four layers (Specht, 2008). These layers are also related to technical infrastructures and solutions engineered for context-aware systems but have been extended with specific components relevant for contextual learning.

The four layers are:

a) sensor layer which handles all sensor information. Key issues on the sensor layer are the integration of wide variety of sensor types, push and pull data collection from sensors, and mobile and infrastructural sensors.

b) aggregation layer in which sensor information is combined into sensible entities and relations, and set in relation to channels and users. On the aggregation layer key processes as aggregation and enrichment take place, these will be described in more detail in a minute.

c) control layer in which the instructional logic is specified. The logic makes use of the aggregated sensor information and enriched entities and combined them in instructional designs. In ubiquitous learning support this layer needs interfaces to the real world objects and digital media as both are used in integrated instructional designs, i.e. the performance or a learner in a certain learning activity can influence and change the status of digital media, learning activities, but also physical objects in the real world.

d) Indicator layer in which all visualisations and feedback for the user are described. Together with the sensor layer the indicator layer holds most of the user interface components with which the user interacts.

In earlier publications we have also shown how to integrate contextual learning support with real world learning environments in museums, industry, or every day life examples (Zimmermann et. al, 2005) and described several applications based on these layers and the components.

AICHE components

In the described four layers different components are used that I have mentioned earlier, these are mainly sensors, channels, artefacts, and control structures. Below I will give some basic definitions of these.

Sensors are all kinds of objects that can measure something. This can be a thermometer measuring the current temperature or a multiple-choice test measuring the student's knowledge about a topic. An important point is that depending on the instructional goals the sensor data can also be used as content in an information channel.

Channels: channels are used to deliver content and services to users. A channel can be a simple output channel delivering information to the user via different modalities, or it can be a combined input/output channel. Input channels allow a user to feed information into the system and therefore interact with the system. Input channels can be bound to sensors and output channels can be bound to artefacts or indicators. The content presented in a channel can be considered to come from a ubiquitous persistence system as "the cloud" and to be described with metadata. Technical problems as the optimal format to deliver content to a channel are solved based on a matching process of available artefacts, the channel, and the content metadata in the AICHE model.

Artefacts: Artefacts are augmented physical objects that allow users to interact with information channels. So basically artefacts can be displays to read information and interaction devices to give input. If a channel is not bound to an artefact a user cannot perceive it. Artefacts are also interaction devices with which the user can produce input as keyboards, audio recorders, video recorders, text recognition engines, sense-based interaction devices and others.

Control Structures combine the entities and a logic description of their dependencies. Simple control structures can sequentially activate the visibility of different channels dependent on sensor information. Complex control structures can describe collaborative learning scenarios with complex interplay of sensors, artefacts, channels, and user behaviour.

For a combination of sensors, channels, artefacts, and the control structures we can define several processes in detail such as aggregation, enrichment, synchronisation, and framing.

AICHE processes

Aggregation

For achieving contextual learning support with sensors it is important to aggregate sensor information to make it meaningful for the learning objectives or tasks at hand. As an example the location of a GPS device carried by a user is only meaningful when it is connected to the user's perceivable environment, and relevant learning tasks. Aggregation can be a quite simple process of converting scales of sensor data, but it can also hold quite complex computations of sensor input as researched in sensor fusion.

Figure 1 shows an abstract example of different sensor values that can be aggregated on higher level sensor categories as described in the operational definition.

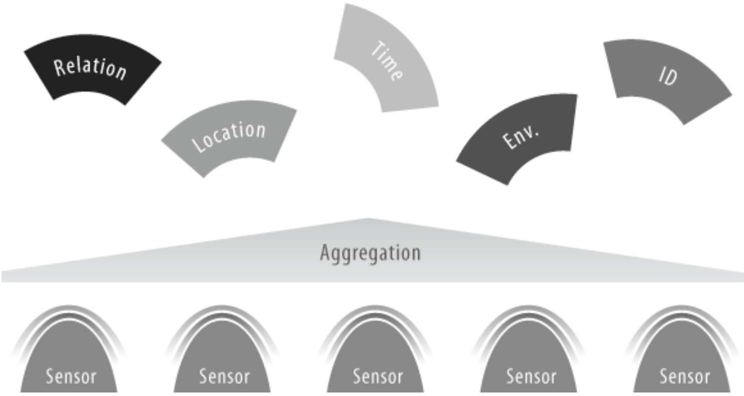

Figure 1: *Aggregation*

Enrichment

In the process of enrichment artefacts, channels, and users are enriched with aggregated sensor information. Either by a specified matching function or by static binding artefacts and users know which sensors can be used for them and what kind of information they can deliver. As a consequence of enrichment each artefact, user, and channel is enriched with context metadata.

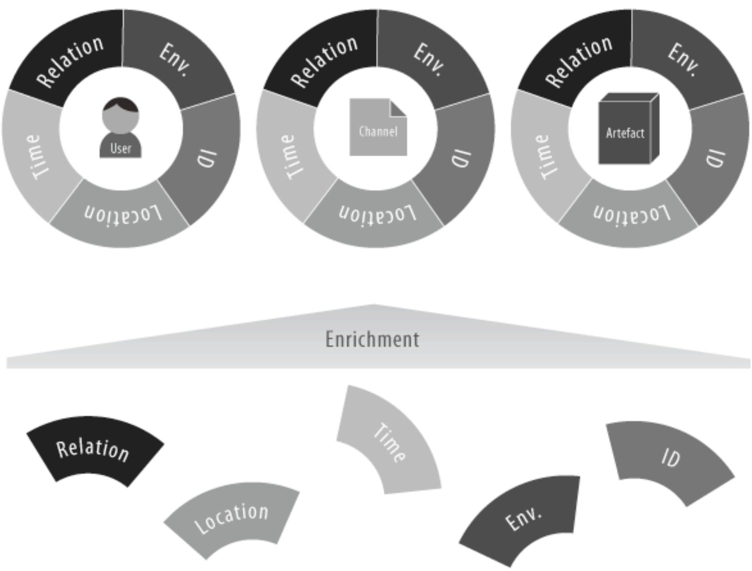

Figure 2: *Enrichment*

Synchronisation

In the synchronisation process the enriched users, artefacts, and channels are synchronised based on a described logic. As an example the location of an artefact and the user are used to display a channel via an artefact. *Synchronisation is at the core of every contextualised learning support*.

At one level synchronisation basically is the result of a matching process, i.e. the user location is matched with location metadata of channels and artefacts. At a second level it becomes evident that the synchronisation has to be based on instructional designs specifying the logic of the matching.

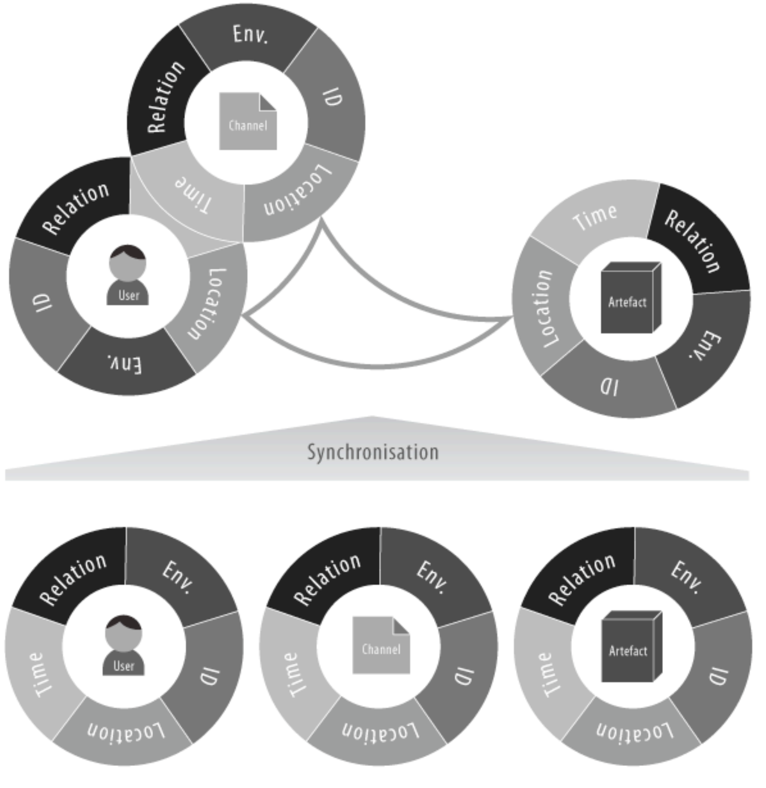

Figure 3: Synchronisation

Location based learning applications are one example of such a logic in which mostly the location is used for synchronising a user, a channel, and artefacts in certain locations. As a simple educational example a podcast channel could be delivered to a user in a museum as soon as the user enters a room. In the example in figure 4 also the time is taken into account for synchronisation. For the museum visitor this could mean that dependent on the time of the day different information will be displayed through the channel. This would require an aggregation of the time sensor onto a categorical parameter of daytime periods as morning, noon, and evening and a specification of the podcast selection for every day period and location.

Framing

Additionally the display of the synchronised channels must be contrasted with relevant reference information in the instructional design. The framing process is mostly related to feedback and stimulation of meta-cognitive processes. In the example the channel presented to the learner can be presented in combination with a second channel displaying an overview of related contents or meta-information about all other artworks from the same artistic period. Especially with augmented reality applications for contextual support framing gets an important role as most artefacts and real world objects with which we learn need to be framed in the instructional context.

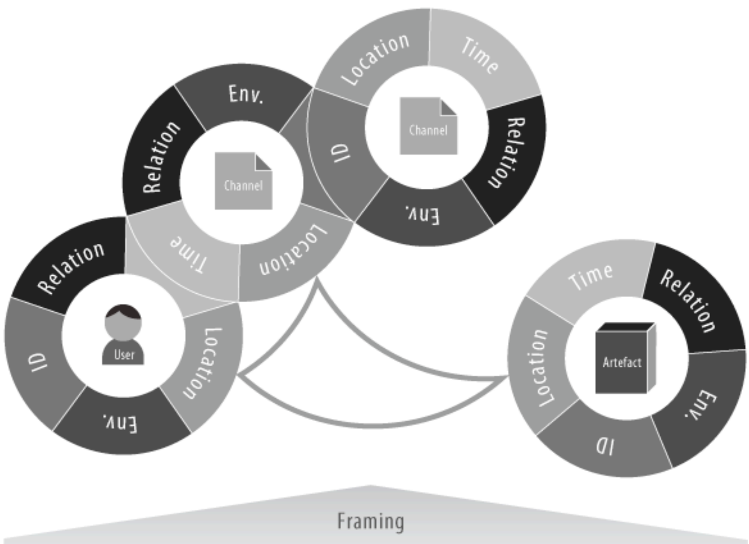

Figure 4: Framing

AICHE examples

The AICHE model can be used:

- for the analysis and classification of existing systems,
- in the design and engineering process for contextual learning,
- in the instructional design for given educational objectives.

Below I will give you some examples of existing systems and describe them in terms of AICHE components.

Conference channels: At most scientific conferences today you can learn about comments and annotations of other participants via blogging or micro-blogging services. Participants can post messages to a shared commenting channel. Any participant can read these messages and the presenter can, for example, pick them up for discussion. In AICHE terms the example uses a *messaging channel*, aggregates micro blogging posts via hash tags, enriches users and channel with the tag information, and synchronises the users social context and environment with the messaging channel, if framing is added the system could automatically calculate the most prominent sessions. In an automatic configuration you would join a parallel discussion channel for every presentation room you enter at a conference either being displayed on your mobile or in a room projection.

Synchronized TV discussions: several products nowadays already begin to combine available digital channels based on metadata. As one example one can use a digital TV receiver to watch TV and to chat with your buddies that watch the same program. In terms of AICHE this combines an information delivery channel (TV Program) with an interactive channel (Chat) contextualized via the program selected and the personal user information about buddies. The interactive channel could be routed to your personal device while the output channel could be displayed on a public display.

Ubiquitous coaching service: several existing services work with notifications to remind users of important learning activities connected to real world activities. Such systems let the instructional designer define a strategy for following up a seminar with real world activities the learner should do after the training in the daily working life. The users receive requests to clean up their desktop or schedule their weekly meetings. The output channel is contextualised to a time schedule of the day, i.e. the notification is delivered always in specified time slots in which the activity typically takes place. The feedback channel of the user is a simple reply message.

In the future we will use AICHE as a model for structuring research questions, innovation stimulation, and representation method for best practice patterns in contextual learning support.

Research Challenges in Contextual Learning

In the following section I will outline some of the challenges laying ahead of us in the area of contextual learning in a technology enhanced world.

Most of these challenges are dealing with some general changes in the way information technology is interwoven with the real world and objects of daily use. We have described several of the relevant research questions in the Learning Media Programme at the Open University of the Netherlands.

The Learning Media Programme is a strategic programme within the Centre of Learning Sciences and Technologies (CELSTEC) launched in 2008. Its goal is to establish innovative, challenging, and pervasive ways of learning and teaching that exploit the opportunities of emerging digital media and media technologies.

So what are the specific research questions we are focusing in the "context of context"?

Content and Context

A first part is to understand how mobile content delivery and injection can be contextualised.

Currently Tim de Jong is working at CELSTEC on his Ph. D. thesis about the mobile delivery and creation of content in context. The underlying problem is going back to a long tradition of research on adaptive instruction. Adaptive instructional systems today cannot only be considered on the level of sequencing information units in a computer-based system but have to take into account processes of multiple channel synchronisation and framing. In his work De Jong considers a variety of contextual filters for information delivery and injection and how efficient these contextual filters are for learning support. This work is mainly related to the synchronisation process in AICHE.

While there is quite some research on how context-aware systems can be built, there is little understood about how learning is supported with context-aware technology.

In further work we will research the use of context indicators and notifications in ubiquitous learning environments in which channels can be distributed between personal and ubiquitous artefacts. This research is following the AICHE model to describe patterns of artefacts, information channelling, and synchronisation and their effects on the learning process.

Reflection in Context

Second the framing of context information to learners plays a key role in our current and future research.

In our research we found how relevant the visualisation of contextual information is for fostering learner's reflection.

As stated earlier in this address presenting information to learners with different contrasts and perspectives is essential for efficient learning support. Christian Glahn working at CELSTEC, who will have his thesis defence next week, has laid the foundation on context indicators with his work. He has researched how personal footprints of users can be used in reflection and fostering meta-cognition in informal settings.

Dominique Verpoorten (Ph. D. student at CELSTEC) will build on this work and will explore the effects of context indicators in more formal educational settings and Personal Learning Environments. The framing of information plays a key role towards a better understanding of information mash-ups used for learning in Web 2.0 and Personal Learning Environments today.

Dirk Börner (Ph. D. student at CELSTEC) is doing research on how mixed reality mash-ups and the distribution of channels across contexts and devices influence the personal sense-making process.

Motivation and Authenticity

A third important research stream is the relation between contextual learning and games.

How can we make use of the motivational power of games in contextual learning support, and how can the continuum between virtuality and reality in games enable contextualised learning experiences?

Sebastian Kelle and Birgit Schmitz (Ph. D. students at CELSTEC) are working on educational games and the use of game patterns in augmented-reality learning environments. Embedding games in real world activities has shown to be even more powerful considering engagement and user experience than virtual gaming worlds.

We expect to identify patters of game design that we can implement in mobile educational games. These patterns would also allow us to describe patterns of aggregation, enrichment, synchronisation, and framing from a more playful and informal learning perspective.

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I have spoken.

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