Journal on Efficiency and Responsibility in Education and Science
ISSN: 1803-1617

KNOWLEDGE IN EDUCATION
A Process View

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Abstract

In this paper we review how changing paradigms of the Information and Communication (IC) technologies affect essential parameters of creating and disseminating information in the academic world. Using a historical perspective their impact on the university education system will be discussed. Both documents (e.g. electronic documents) and communication means (e.g. Internet) are investigated. The parameters are analyzed with respect to their effects on the timing of the various subprocesses of academic education (e.g. time to publication, time to teaching etc.). Consequences for quality attributes and teacher/student relationships are discussed in view of the academic education processes. We will show that many of the cherished traditions, habits and beliefs of yesterday are invalidated, especially by the modern IC-technologies.

Key Words

Educational Processes, Information and Communication Technologies, IC-technologies, academic education, time delays.

"... the times they are a-changing"

(Bob Dylan 1964)

1 The Knowledge Life Cycle

1.1 Knowledge and Education

Changes of the Information and Communication Technologies (IC-Technologies) from handwritten manuscripts archived in medieval monasteries to texts freely distributed with electronic speed via the Internet have considerable impact. They have (and still will) change our understanding and interpretation of the notion of knowledge, education and how it is to be provided and administered.

The paper is structured as follows: In the current chapter we will expand the notion of knowledge and its creation. Chapter 2 lists all interesting technologies, both with respect to creating documents and transmitting information. In chapter 3 we discuss the classical academic knowledge dissemination process and its individual subprocesses. For these subprocesses we will identify essential parameters, especially with respect to performance time. For each of these processes we note the changes in performance due to technological advances in information and communication technologies. Chapter 4 is devoted to discussing certain synergetic consequences of the parameter changes of the various subprocesses like teacher's lead time, verifiability, etc. In the last chapter 5 we discuss future global changes to some of the sometimes cherished traditions of academia.

1.2 The SECI Knowledge-Creation Model

A basic distinction exists between explicit and implicit knowledge (Nonaka and Takeuchi 1995) as indicated in fig. 1. Explicit knowledge is defined as „knowledge that has beenor can be articulated, codified, and stored in certain media. It can be readily transmitted to others" (2005 Wikipedia, → explicit knowledge). Today such knowledge can easily be processed by a computer, transmitted electronically, or stored in databases. External knowledge is contrasted to „tacit knowledge" which „is knowledge that people carry in their minds and is, therefore, difficult to access.

Effective transfer of tacit knowledge generally requires extensive personal contact and trust „ (2005 Wikipedia, → tacit knowledge), see also (Skok 1999). Fig. 1 shows how tacit knowledge is transformed into explicit knowledge via the process of externalization.

In this paper we will concentrate on the transfer (dissemination) of explicit knowledge, a major objective of university education.

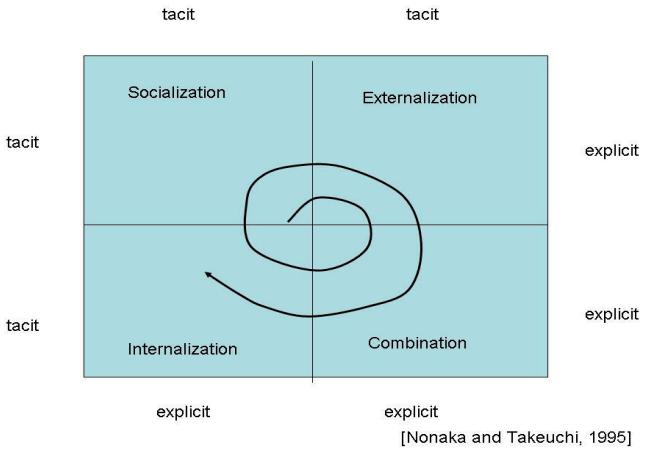

Figure 1: The SECI-Model of knowledge creation (Nonaka and Takeuchi 1995)

2 Technologies and their Properties

2.1 Education, Communication and Technology

One of education's main purposes is to create knowledge in the people to be educated (there are some other purposes like socialization etc., but this will not be discussed further). Even if there is no accepted definition of the notion of knowledge (cf. 2005 Wikipedia →knowledge) we know that a large part of knowledge acquisition is based on passing knowledge ultimately from one

person to another. As fig. 2 shows the Originator and the Recipient of some information (knowledge?) have to share a common communication channel and the information itself needs to be stored on some kind of medium. The figure also

indicates that it is necessary to distinguish between volatile and persistent media.

In the discussion of the academic education process persistent media play the key role. The receiving person adds the new knowledge via the process of combination to the existing one. This means that actually we accept that "Knowledge is based on Information", differently formulated "Knowledge is remembered ('stored'→ information" 2005 Wikipedia Deutsh, → translated from 'Wissen'). Information itself is understood as "meaningful data".

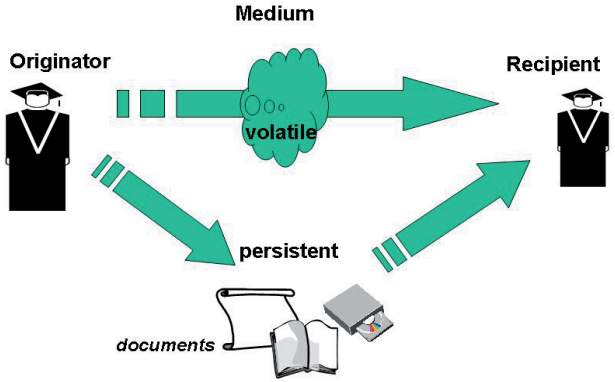

Figure 2: Basic Communication Processes

More precisely we should say that data are passed from one person to another which are interpreted as information and used to create knowledge in another person but otherwise we will ignore this fine point.

The desire and the ability to disseminate knowledge is one of the keys to scientific research (Schneider 1996). Scientific research implies not only the passing of scientific knowledge, it also aims at *"the acquisition of knowledge in a systematic, methodical process with intersubjectively reconstructible and purposeful research"* (Haux et al. 1998, p. 9).

By using knowledge from our predecessors we try - *as Newton formulated it* - to stand on the shoulders of giants, our predecessors.

Despite the fact that information itself is immaterial and clonable without any loss, it is necessary to bind it to an appropriate medium (see section 2.2). The information contained in this type of medium has to be communicated by an appropriate 'carrier' (see section 2.3). IC-technologies over time, but especially the last 50 years have dramatically changed both the available media and usually in parallel the communication technology (Kraut et al. 1994). Many of these changes often implyradical changes to knowledge dissemination and education.

2.2 Communication Media

The various documents usable as information media are listed in figure 3. Most of them are a product of the last 50 years, produced by IC-technologies. The figure shows relevant types of documents types together with their essential properties.

Dramatic changes in our times provide two outstanding media: electronically produced documents (e.g. desk top publishing, electronic office) and - a little bityounger - electronic documents on the World Wide Web.

Document typew paradigm	max info size	tool cost	effort producing instance	reprod. cost	
Handwritten text (fixed location)	persistence	medium	small	small	same as original
Handwritten text (mobile medium)	transportable information	medium	small	small	same as original
Handwritten books	aggregated information	large	small	very large	same as original
Type-set books	reproducibility	large	medium	large	small
Xerographic copy	cheap and fast reproducability	large	medium	very small	small
Electronic document / desk top publishing	variability of fonts, independence from printer	large	medium	small	very small
WWW document	self-representation, no restrictions	medium	very large	small	very short
Virtual reality	imagination, irreality	medium	very large	small	small
RFID-tags	active recognition, unobtrusive communication	small	small	very small	very small

Figure 3: Properties of Documents

Essential properties of these document types are:

new paradigm: What is the new paradigm introduced by this technology? A careful analysis would show that some of the later media often do not preserve properties of previous media, but since all document types essentially can be used in parallel this is no problem. The 'new paradigm' in many cases, however, was the 'unique selling point' for the introduction of that medium.

maximal information size : How much information (data) can be feasibly transported?

tool cost: What is the cost/effort of tools needed to produce the document? Typically producing color photo-slides needs an appropriate studio.

effort producing instance: What cost/effort does it take to

produce a single instance of the medium? Although producing a desk-publishing tool like LATEX (Goosens 2000) or WORD is a tremendous effort, writing an individual document is very easy.

reproduction cost: What is the cost of producing a similar copy of an existing document?

2.3 Communication Means (Carriers)

In this section we discuss the essential technological advances of communication (Kraut et al. 1994), (O´nils and Jantsch 1997), (Tarumi et al. 2000). The advances in technology go hand in hand with the advent of new information media (see section 2.2) which can serve to transport the actual information. Sometimes a clear distinction between medium and communication means is difficult. In fig. 4 we list essential communication means (see also (Chroust 1998) and (Chroust 2005)) together with the significant technological advance they have brought about.

The technologies are listed roughly in the order of their historical appearance. Only a few of them are of high relevance for the education process. We also list some of their essential properties which are of importance for the education processes (fig. 4).

These carriers come a long way from the initial start-up of oral communication: In the oral tradition (this has been included to stress the difference to today's communication means) the information was passed on synchronously from the Originator to the Recipient. No written records existed. No verification by regression was possible once the Originator was dead. Even if the Originator still lived it was often impossible to contact him/her. The lack of original written documentation is typical for most existing religions (cf. (Detering 1995), (Smith 1973)).

Carrier	new paradigm	proto-coll	aura of sender	max info size	delivery speed	fan-out	infrastr. prep. effort	instance product. effort
Speech	abstraction	push	small	medium	fast	1:n	null	null
messenger	spatial difference	push	small	medium	?	1.1	null	null
letter mail	organized service	push	small	medium	medium	1:1	large	very samll
Telephone	inter-activity	push	small	small	fast	1;1	large	null
Television	dynamic images	push	large	medium	fast	1:n	very large	large
Fax	graphics	push	small	medium	fast	1.1	large	small
e-mail	machine readable, fast dissemination	push	small	medium	very fast	1:n	very large	very small
Groupware, tele-conference	cooperation	push / pull	small	small	very fast	m:n	medium	small
Internet, WWW -publishing	self-presentation, no restrictions,	push / pull	very large	medium	very fast	m:n	very large	small / medium
Ubiquitous Computing	immediate access	pull	possibly large	medium	very fast	1:n	very large	small
Agent technology	delegation, asynchronous execution	push	small ?	medium	fast	1:1	large	large
smart objects (e.g. RFID)	fine-grained identifyability	pull	small	small	very fast	1:n	medium	small
subconscious, ESP techniques	access to subconscious	?	small	?	?	1:n?	?	?
intrusive techniques	neural manipulation	?	small	?	?	?	very large	?

Figure 4: Properties of Carriers

Of key importance to the changes in education are:

e-mail: The message allows for fast dissemination in asynchronous form. It is essential that the transmitted documents are electronic themselves and can be immediately and seamlessly processed further. The ability to attach further

arbitrary documents (including graphics, sound etc.) enhances the importance.

Groupware, teleconferencing: It allows a limited number of persons to have a virtual common meeting, irrespective of the geographic location of these persons. Computer support provides numerous helpful tools for brainstorming, voting, recording, minute writing etc. (Boehm, Gruenbacher and Briggs 2006), (Grünbacher and Chroust 1996), (Bächle 2006).

Internet, WWW -publishing: The World Wide Web allows 'individual self-promotion' by posting something 'to the web'. Anybody is able to put a 'publication' into the Internet, be it a scientist or an ignoramus. The effort to produce one instance is small to negligible. It is often already hidden in the effort producing the associated creative work.

Putting documents on the Web circumvents quality control, reducing total time-to-publication essentially to the part of the preparation time which is used to finalize text and figures and formatting it for web-usage. Since everybody has easy access to this 'published' material the acquisition time is also reduced to zero.

Agent technology: Agents have a activity of their own and can be programmed/instructed to perform tasks independently. They can roam the Internet for material etc. (Lieberman and Mauslby 1996), (Payr and Trappl 2004).

For each technology of the technologies listed above we show a few of their key properties in fig. 4:

new paradigm: What is the new paradigm introduced by this technology? A careful analysis would show that often later technologies do not preserve these properties, but since all carrier types essentially can be used in parallel this is no problem. The 'new paradigm' in many cases, however, was the 'unique selling point' for the introduction of that medium.

type of protocol: The information can be supplied somewhat in a push fashion, i.e. initiated by the Originator or can be supplied 'on-demand', i.e. in a pull fashion.

aura of sender: What size can a group have such that the producer can still communicate effectively?

max info size: What is the amount of data/information to be transmitted conveniently?

delivery speed: How fast is the transmission? The interesting IC technologies provide practically instant transmission

fan-out: How many recipients can be reached with one communication action?

infrastructure preparation effort: What is the cost of the infrastructure to enable people to use this carrier? Typically Internet, easy as it is to use, needs a tremendous effort for its upkeep.

instance production effort: What is the effort to produce a single communication act.

3 The Academic Education Environment

We want to point out that in this paper we concern ourselves almost exclusively with the academic education environment. Many of the facts and observations will carry over to other domains, but this would need an additional research effort.

3.1 Basic Processes in Academic Education

Basically academic institutions try to pass the knowledge from one generation to the next: a teaching process (fig 2).

In the simplified model of teaching (fig. 5) we use only four prototypical roles:

the Originator: This role creates some (new) knowledge which is valuable and is considered to become a part of the scientific knowledge base. This knowledge has to be disseminated. In fig. 6 we show the essential steps of a (classical) dissemination process. Once a book etc. is available on the market it is a candidate for being used in knowledge dissemination (and further on for teaching).

the Teacher: This role acquires (scientific) knowledge (it is usually also an Originator) in order to pass it on to the Student, by teaching. In fig. 5 we shown the various steps in the process: from the acquisition of the document containing the new knowledge, through understanding the material, to preparing material adequate for teaching and the actual teaching process.

the Student: This role is trying to learn the scientific knowledge available. He/she usually will follow some academic curriculum.

the Distributor: This is a subordinate, but essential role. It is in of distributing the documents containing the knowledge, nowadays it is usually a publisher, in Internet-times sometimes also an automated software programm.

The same person may participate in these processes in several roles: By law Austrian Universities have to follow 'research-based teaching', the academic staffperforming both Originator and Teacher roles.

In more detail we can distinguish seven different subprocesses (fig. 5).

dissemination: The Originator makes some knowledge available to others by publishing it in an appropriate form: it becomes explicit knowledge, fig. 6, section 3.2.

identification: In order to acquire additional information (knowledge) potential sources of information must be identified. If they are useful, the information in the respective documents would be acquired, fig. 7, section 3.3.

acquisition: The Teacher acquires this knowledge. This includes getting access to the medium where the information is stored. He/she combines it which other existing knowledge (cf. fig. 1) in order to gain understanding and consequently being able to teach it, fig. 8.

teaching: As the next step the knowledge is taught to the students, usually prepared in an appropriate way and often accompanied by (secondary) explicit knowledge, fig. 5, section 3.5.

regression: Especially the Student might want to access the original basis of the presented knowledge in order to check the validity and/or the interpretation by the Teacher. Additionally the Student might want to get some more details, more background or even a second opinion, fig. 5, section 3.6.

searching: In the course of preparation the Teacher might search for additional/supporting or undermining material. Likewise the Student might be interested in knowing more supportive material and would also engage in searching for more material, fig. 7, section 3.7.

browsing (serendipity): In the course of searching or regression the Teacher or the Student might run across other knowledge which is relevant for their work. Drawing a border between goal-oriented searching and undirected browsing is often difficult to draw especially since a user often switches from one type of work to another (searching something, finding something else of interest, searching on the new question etc.), fig. 7, section 3.7.

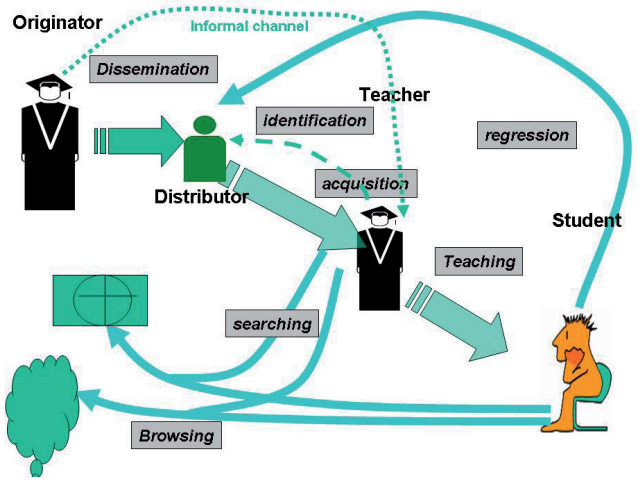

Figure 5: Basic tasks in the Education process

In the next sections we will describe the processes identified above in more detail and discuss the effects technology has on them. We explicitly distinguishdelays due to work and delays due to communicating with somebody else (communication delays, e.g. C_{PREP}, C_{EVAL}, C_{PROD}). We will show that especially the communication delays experience considerable reduction due to modern technology.

3.2 The Knowledge Dissemination Process

In the sequel we will only concern ourselves with communication via persistent media which is especially important in the dissemination of scientific knowledge.

Fig. 6 shows the key time delays in the dissemination process. The delays are:

Time for preparing the manuscript (T_{prep}): A certain time is needed (after/during the conceptual, mental work) to produce an appropriate manuscript. Usually some help from a specialist was needed for the preparation, be it a monk writing on parchment, be it a secretary writing the manuscript.

Transmission delay of submission (C_{prep}): This is the time needed to send thedraft (manuscript, typescript) to the evaluators (programme committee, editorial board, ...)

Time for Evaluation (T_{eval}): Knowledge submitted need not to be correct or valid. For scientific books, journals and proceedings of conferences a verification subprocess (performed by editorial boards, programme committees and reviewers) is standard, ensuring a certain quality of the published material. This activity is obviously the cause for considerabledelay, especially for books and journals where several iterations between reviewers and the author are not unusual.

Transmission delay of evaluation (C_{eval}): This is the time needed to send thefinal manuscript to the actual publisher or printer.

Time for Production (T_{prod}): It takes extra effort to produce a book/journal for accessability/distribution to a wider audience. Typesetting and proof reading take considerable time. The next step is actual printing the book and then binding the volumes. With the advent of desk-top publishing and the habit of requiring the submission of camera-ready copies this effort

has been drastically reduced. With the printing process the end of production is reached and the book/journal is ready for the general public to be accessed/acquired. The new knowledge becomes accessible to a (sufficiently large) public.

Transmission delay of produced document (C_{prod}): Time to send the material from the printer etc. to the final destination, be it an archive, a library or a distributor (book store, conference, journal mailing etc.).

Aggregation of above delays yields the externally relevant time delays:

Time to Acceptance (TT_{accept}): This is the time from the initial start of creating the document until it is deemed ready and accepted for publication.

Time to Publication (TT_{publ}): This is the time from the initial start of creating the document until it is available for the public. We ignore the overlap between conceptualization and actual writing, since this does not have much influence.

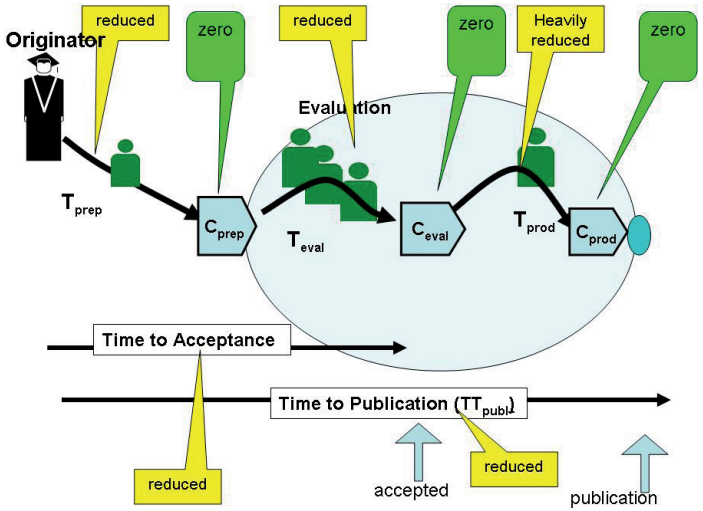

Figure 6: The Dissemination Process

In fig. 6 we left out potential feedbacks, iterations and rework, which is not really calculable and also does not considerably change the effect of technology, except to supply a multiplication factor.

Analyzing the individual delays as shown in fig. 6 we come to the following conclusions:

- Communication delays are reduced almost to zero.
- The time for preparing the manuscript is reduced due to the use of modern desk top publishing means, including drawing aids (e.g. Power Point, available clip art, etc.).
- The evaluation process is shortened due to the availability of Groupware support, virtual meeting support, and the

fact that documents under evaluation do not have to be physically copied.

- In the production of the final document (e.g. book) the seamlessness of electronic documents make a transfer step (or even a type setting step) unnecessary. Many production systems use the author's input directly to control the printing machines.

A typical example is the submission process to conferences. 20 years ago there were 3 to four month of elapsed between the deadline for submitting a paper and the final proceedings ready for print. Today this can be compresses to four weeks without any problem.

Semi-automatic conference systems (Van de Stadt 2002) offer several further advantages:

- The electronic submission allows for immediate comparison of the decision of the various reviewers and enables them to discuss their decisions and even to change them with electronic speed.
- Reviewers can see all documents (not just the ones the programme chair sends them) since (electronic) duplication and mailing creates practically no effort.
- The conference programm is automatically generated afterwards.
- Slight modification to accepted papers (e.g. reformatting) can be done by the authors (or sometimes even by the editors) on short notice according to the reviewers' suggestions.

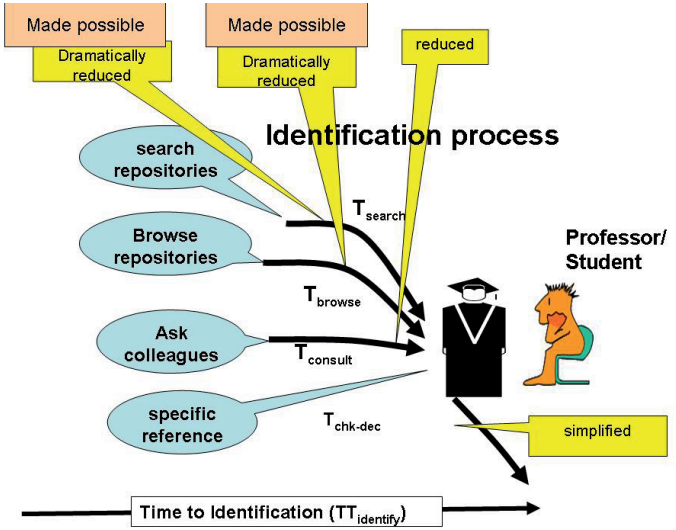

Figure 7: The Identification Process

The identification process tries to identify sources of additional knowledge to be accessed. Basically there are three sources:

- specific pointers to documents from other documents or colleagues,
- documents identified by systematic search,
- documents accidentally found via browsing (serendipity).

In most cases only references (pointers) to the documents are provided, the exact source and the actual acquisition are separate processes.

Time for searching (T_{search}): This is the time needed for a targetted search. This is dramatically reduced due to electronic speed. Additionally searching for certain documents or information would have been practically impossible without digitized documents.

Time for browsing (Tb_{rowse}): There are many ways for finding out about relevant knowledge. They reach from being notified, to consulting a colleague, to explicitly search, to accidentally find something by (undirected) browsing (serendipity). With globally available and accessible document bases (e.g. electronic digital libraries) search and browse meant day-long stays in various geographically distributed libraries, asking for copies and waiting for their production.

Time for consulting ($T_{consult}$): Asking colleagues is a matter of communication. Modern communication reduce this time investment and eliminate mailing delays.

Time for source-checking/deciding ($T_{chk-dec}$): Having found a promising document candidate it is necessary to check the validity/reputation/credentials of the document. Not every document offered to the public, even if it is printed, comes from a reliable source which ensures the document has passed some quality assurance process. Detecting (especially on the Internet) a promising looking document could still turn out not to be what was promised initially. Thus one has to be careful. For well-known publishers or conference organizer checking can easily be done by looking at the names and the credentials of the publisher/organiser. For other sources it might take longer or it can even be impossible (especially on the Internet (2002 Univ. of Michigan)). In the Internet is also necessary to make sure that the document is the original unmanipulated work of the author(s). This situation is similar to the software markets with so-called Software of Unknown Pedigree, "SOUP" (Hart 2003).

Time to identification ($TT_{identify}$): This comprises the total time until a piece of information, a document, is identified. Some of the activities are only made possible by digitalization, others are dramatically reduced in time and effort. Many of these activities can be performed in parallel. Analyzing the individual delays as shown in fig. 7 we come to the following conclusions:

- Without global search mechanisms it was necessary to visit several libraries to make searches.
- Comprehensive search functions (especially full text searches) are only possible by IC-technologies. They culminate (at the moment) in digital libraries. Agent technology (the first step into this direction is GOOGLE) will further improve the effectiveness.
- Browsing through hundreds of documents was a tremendous task without electronically stored and searchable documents.
- Consultation with colleagues is made easier with electronic media.
- Very often one not only receives an identifier of a document but the document itself, saving the ordering process.

3.4 The Acquisition Process

We consider the Acquisition Process (fig. 8) finished when the knowledge has been combined by the Teacher with his/her existing knowledge (cf. fig. 1). Therefore the process has two components:

- acquiring the documents containing the desired knowledge - and - if necessary - waiting for it,

- finally trying to comprehend the acquired information.

Essential delays are:

Time for Placing Order (T_{order}): Placing the order (or in medieval times arranging a visit) might involve considerable delay. Besides the potential formalities of the 'ordering' process there will be some communication delay. Paying for documents was also a problem before electronic banking etc.

Order Communication Delay (C_{order}): Communicating the request for the document will cause some delay. In the old days letters had to be written.

Time for Request Processing ($T_{order-prc}$): Once the request is received its processing will need some time until the request is granted (or not!). This processing could include checking the privileges of the requestor to see that document (e.g. when ordering from a consulting organization) and/or making the necessary financial arrangements of the order.

Delivery Delay ($C_{deliver}$): In medieval times acquisition of knowledge usually meant physically travelling to some often remote place (a monastery) to be allowed to read the manuscript/book there. Very often these books were chained to their support for added security ('chain books'). Today scientists interested in printed books/journals have to order them and receive them by mail sent (causing some mail delay). In the case of Internet it might be possible to load the material down to one's own computer and have it for immediate local availability. For valuable rare books even nowadays it is necessary to request copies by some loan mechanism or even go to their safe-keeping place.

Time for Comprehension (T_{compr}): After having the document in one's hand it is often a considerable effort to read it, understand it, draw conclusions and finally be ready to prepare the material in a way suitable to be taught to students. Electronic documents offer there some help by being able to be formatted, searched etc. Also all the other electronic tools available for research come handy.

Time to acquisition (TT_{acquis}): Analyzing the individual delays as shown in fig.8 we come to the following conclusions:

- Due due electronic ordering, electronic payments etc. the actual ordering act is considerably reduced.
- The actual time for transmitting the order is eliminated.
- The processing of the order will usually be reduced to electronic means.
- If the requested document is electronic itself, then again the transmission time is put to zero.
- The actual comprehension process is supported by numerous electronic means and tools and thus eased.

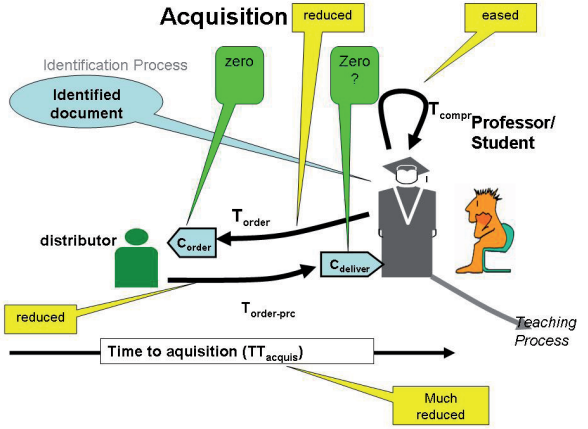

Figure 8: The Acquisition Process

3.5 The Teaching Process

This process starts with the decision of the Teacher to pass the newly acquired knowledge on to the students.

Time for Material Preparation (T_{mat}): There is still a large step between understanding a topic oneself and arranging it in a form amenable to be taught to students (cf. (Berg and Huber 1996), (Ossimitz 2000), (Carryer 2002), (Perritt 2000)).

Lecturing Delay (T_{lect}): Usually there is a certain delay between having the delivery readiness and actually delivering the lecture to students.

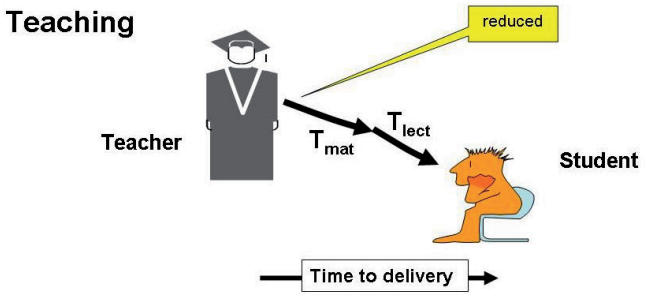

Figure 9: The Teaching Subprocess

Analyzing the individual delays as shown in fig. 8 we come to the following conclusions:

- The process of material production will be basically simplified by the new tools.
- There has appeared, however, an opposite trend in the students' expectations with respect to the formal quality of the presented information to the with the availability of modern presentation means. As fig. 10 shows the preparation effort to produce modern presentations means, using a notebook, a beamer and perhaps producing a multimedia show is rising.
- At the same time the flexibility during the lecture is reduced: during a presentation a power point presentation offers considerable less flexibility (e.g. for switching the sequence of pictures) than a overhead presentation or the writing on the blackboard.

3.6 The Regression Process

The motive for the use of the regressions process (both for Teacher and Student) is either to verify the delivered knowledge or to learn more about it by accessing the original document. The process of trying to locate the original document is essentially the Identification Process (section 3.3, fig. 7), assuming that a precise reference is available, otherwise a search process would be needed. Despite the fact that the Teacher might have identified a source, the document there might not be available, or not accessible, or prohibitively expensive to buy. In this case a search for a second source might be useful, e.g. nowadays on the Internet.

Medium	preparation time (P_{mat})	ease of presentation support	flexibility at lecture
Speech	null (only mental)	null	fully
Blackboard	small (only mental)	? hand-write everything !	fully
Diapositives	days	medium	null
Foils handwritten	hours, cumbersome	medium	medium
Foils (electronically produced)	hours	medium	small
Beamer/Notebook	**more hours**	**large**	**very small**
Multimedia	several days	medium	**null ?**
Internet, WWW-publishing	many days	large	null

Fiure 10: Delays in the Teaching Process

3.7 The Search and Browse Process

Although there are certain differences we will treat both searching and browsing together. A reason is that a user very often switches between the two modes. Both processes are already discussed under the heading of the Identification Process (section 3.3, see also fig. 7).

3.8 Informal Channels

We have to recognize that there are also some informal channel, especially for the Teacher: contacts with other colleagues, being on distribution lists of available knowledge etc. Modern technology (e.g. Web 2.0) will enhance this trend to "social software" (Bächle 2006). Examples are recommender systems (Balabanovic and Shoham 19997), (Bonhard et al. 2006), Electronic Performance Support Systems (Banerji 1995), groupware in all forms (Bonhard et al. 2006), (Gross 1997), (Selvin 2003). The classical knowledge dissemination process as described in Fig. 5 does not show an informal information flow between scientists. Informal communication at conferences, letters, and e-mail exchanges make a scientist well aware of the activities of the colleagues in his own field. Thus the appearance of a new document (e.g. a paper) by a well-known colleague working in the same field will not cause much of a surprise. Very often the Teacher might even have received a pre-publication copy or heard a presentation on the topic.

These effect of the informal channels have (amongst others) the followingeffects:

- faster notification of appearance of new knowledge,
- better chance to get feedback from colleagues,
- wider distribution of information, especially if a large aura (Gross 1997) of the Originator's e-mail enhances the information flow (cf. fig. 4),
- easier sharing of draft versions (cf. fig. 3) in order to hare information and the exchange opinions.

4 Technological impacts on the educational processes

There are several aspects in the technological support of the educational process which have been, sometimes dramatically, changed by technological improvements. We will discuss some of these aspects in the following sections.

4.1 Teacher's lead time

Dissemination of knowledge needs a certain temporal lead-time for the Teacher. This is the amount of time the teacher gains by acquiring the knowledge earlier than the Student. He/she has to acquire information, analyze, and comprehend ('digest') the material and finally prepare some teaching material, see fig. 9

and (Chroust 2005). Only then is the Teacher ready to lecture about this subject and to pass the derived knowledge to the Students.

4.2 Verification by the Student (regression)

The Student might himself/herself cross-check the statements a teacher made, i.e. verify the statements of the Teacher. Having been confronted with the subject only in the lecture (fig. 9), it takes some time for the student to follow up.

4.3 Surprising the Teacher

The Student might by chance (e.g. browsing) come across some knowledge and present it to the Teacher, perhaps in order to impress or embarrass the Teacher. The actual document (e.g. a paper or even a book) might be unknown to the Teacher. Usually we expect a Teacher to be aware of his/her field of expertise also via informal channels. How much surprise does the newly shown document hold for him?

The value of lead-time could easily become negative in the sense that the Student is 'faster' than the Teacher and thus is able to 'surprise' the Teacher. Some of the conditions for avoiding this situation are:

- The Student is unable to acquire the document at all.
- The acquired document is so difficult to read/interpret that the Student 'gives up'.
- The Teacher is highly familiar with the environment from where the document comes has a good estimate of the document's content due to some already received informal channel.

If one analyzes the history of dissemination of knowledge, taking into account historically older communication means and carries (oral tradition, handwritten unique books, printed books camera ready produced books, e-mail and world wide web) one can depict the lead-time of the Teacher in comparison to the Student approximately as shown in fig. 11.

4.4 Verifiability and follow-up

Verifiability is related to the time it takes for an outsider (e.g. the Student) to verify the statement of the teacher. The Time-to-Regression has been identified and characterized in section 3.6. As it is shown there IC-technologies allows a much faster regression to knowledge. Verifiability, however, assumes that the document is either persistent or at least that changes can be retraced. In the case of Internet, this is not true, such that withWorld-WideWeb the Verification Ability is reduced (fig. 11).

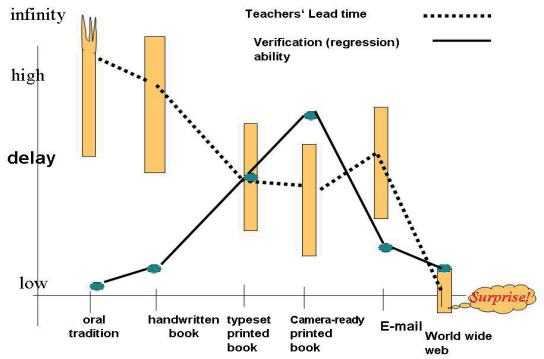

Fig. 11: Lead time and verifiability for various dissemination methods

5 Consequences of IC-technologies

The discussions in this paper allow several conclusions on some of the directions for the future.

dramatically reduced time to publication and to teaching: The reduction of these very important time spans has several reasons:

- Most obvious and also of high impact is the reduction of various transmission times to practically zero.
- The increased aura of the Originator allows more parallel work without (often expensive) physical copying.
- Many of the knowledge related processes, especially document processing, experience a certain speed-up due to more 'intelligent' tools.
- Search and browse processes are sped up by factors of magnitude.
- The ability to efficiently copy/duplicate documents also contributes to speeding up the processes, often (although not explicitly addressed here) the danger of plagiat (Kock 1999) and violation of copyrights.

Improved availability: Electronic libraries with electronic copies also of back issues considerably improve access to knowledge.

Improved verification potential: The global availability of electronic documents and the speedy access to them allows fast and efficient verification. The question of verification via regression could be handled by an electronic equivalent of a Library of Congress.

Lost Lead-time: With respect to academic teachers the problem of lost lead-time (students have documents in their hands faster than the Teachers (Chroust 2005)) requires more awareness of a Teacher and perhaps a more up-to-date awareness of developments in his/her field. One of the results could be that Teachers achieve a new understanding of their role : more mentors and moderators than classical teachers.

Unrestricted publication in the Internet:

- Submitters outside the established scientific community, not being bound into a network of peers, have a better chance to make their arguments, ideas public via the Internet.
- The flexibility and short-livedness of the Internet document base endanger the persistence of and thus the trust into the document archives in the Internet. This undermines the advantages gained by faster and better regression.
- The possibility of direct, unconstrained publishing endangers the quality and solidity of the educational processes and their documenting base, especially with respect to searching and browsing. The filtering mechanism which helped the Teacher to distinguish 'valid' from 'invalid' knowledge via publishers and selected peers is not applicable to the Internet.

6 Conclusion: Changes to academic education

The facts and trends indicated above force us to rethink some of the academic traditions established over centuries. Some changes are/will be:

from collector to hunter: The value of accumulating information will diminish in favour of a just-in-time hunt for the latest information on a given topic (Schneider 1996), abolishing 'shadow copies' in one's file cabinet.

from teacher to guide: Teachers have to guide and advise more and to lecture less. And they have to accept the sudden appearance of hitherto unknown information.

from believer in printed text to critical reader: The flexibility and the loss of some verifications mechanisms due to the unrestricted publishing capability of the Internet forces us to strengthen our criticality when acquiring documents especially from the Internet from stability to volatility :We will have to live with the fact that the information which we acquire from central sources will be unstable, volatile and often changed. Ways to ensure the permanence and authenticity of results once published have to be designed.

from territorial autonomy to global competition: Without globality a Teacher could establish his/her own terminological and conceptual system within his/her sphere of influence. Nowadays this is not possible anymore due to the permanent availability of documents on the Internet. Now the lack of a consistent terminology is felt very strongly and arises in many situations.

As one can see there are some dramatic changes to come to the academic world, many of them are already there but have not yet been fully understood or put into effect. There is still some work to do!

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