AC 2007-1812: ANALYSIS OF ELABORATED ADOPTION PROCESSES TO IDENTIFY THE OPTIMAL STRATEGY OF LEARNING

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Analysis of elaborated adoption processes to identify the optimal strategy of learning

Introduction

ELearning has raised great expectations and promises, which have not been reached by now. Both effectiveness and sustainability have not been accomplished in the anticipated degree. Engineers with their conservative teaching style are particularly critical on eLearning techniques. Two reasons for the negative esteem of eLearning will be shown in this paper.

Many experts anticipate that eLearning is growing as quick as information technology. But this is impossible due to the fact that the innovation speed of context free computer science is much higher than context associated learning and teaching software. A teacher needs three years to optimize his lecture and this does not correlate with the development cycle of computer science.

We can neither affirm nor negate, that the use of eLearning itself causes a learning process improvement. Alike traditional teaching, eLearning has to live through its own evolution process to reach a certain level of quality. This evolution has to take place in a slow speed. If the strategy is too revolutionary it is impossible to compare the evolutional step with the initial situation[1].

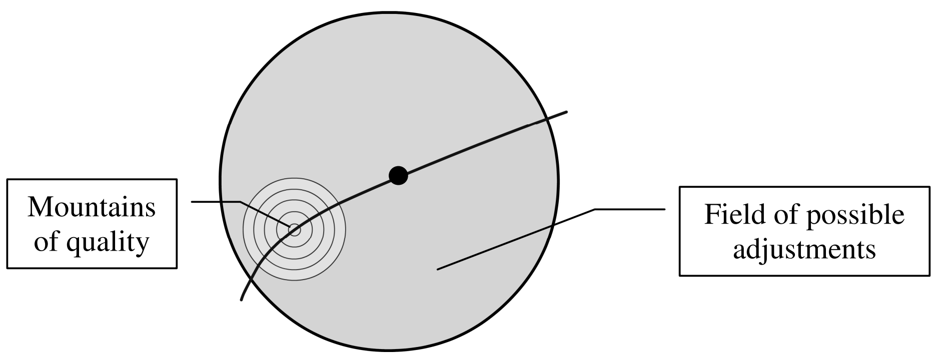


Figure 1: Improvement depending on causality

Figure 1 explains this problem. The center describes the initial situation. The outer circle describes the modification of the current situation. The bigger the diameter the more revolutionary is the system. The lower left circle describes the area, where an upgrade of the systems quality can be achieved. If change is too big the upgrading circle will be passed without improving the quality.

Here quality stands for an objective performance in terms of criteria defined by several quantity and/or quality characteristics. To improve the quality of eLearning systems in effective and sustainable manner, the following processes are necessary.

- Determination of quality criteria
- protection by generative means
- improvement by iterative means.

One way of improving the quality is that the eLearning system experiences feedback in a process loop. The results will be given to the system after it was used. The effective adjustments of the processed system observations describe the potential adjustment of quality. With the aid of the quality criteria it is possible to upgrade the quality of an eLearning setting by selective adjustments.

It will be shown how a standard university lecture of civil engineering education can be transformed into a modular eLearning course. The traditional university lecture is not insufficient; the eLearning setting will complement the lecture in a combined learning setting, which we call *blended learning*. We begin with the traditional layout of engineering studies in Germany. Then the modular architecture of a course will be used to create an also modular common learning setting. With the aid of the links between the discrete modules a learning network accrues, within which the learner can move. To achieve a sustainable, economical priced and effective application the transfer of the content in a Wiki engine will be shown. The educational objectives of a common learner will be discussed. Finally we will demonstrate how to upgrade the quality of the eLearning setting by a systemic feedback loop using real time usertracking.

Application in a course of "Steel Construction" – Civil engineering courses in Germany

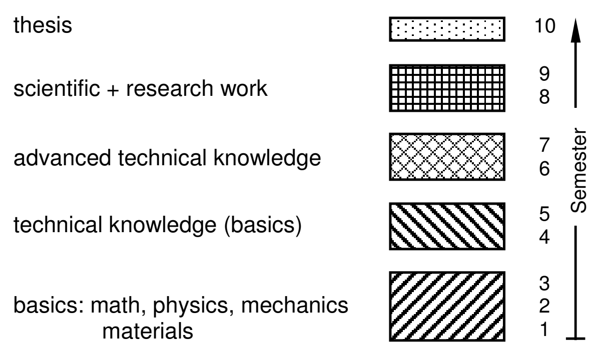


Figure 2: Set up of civil engineering courses in Germany

Civil engineering courses at German universities start with basics: mathematics, physics, geodetics, mechanics, etc. After that the students get the basic technical knowledge in subjects as steel construction, concrete construction, static, hydraulic engineering, etc. The next step is an advancement of the student's technical knowledge based on scientific work. A research oriented thesis ends the program. In general the study can be classified into three levels.

1.) Basics (B)
2.) Basic technical knowledge (BK)
3.) Scientific work and research (SR)

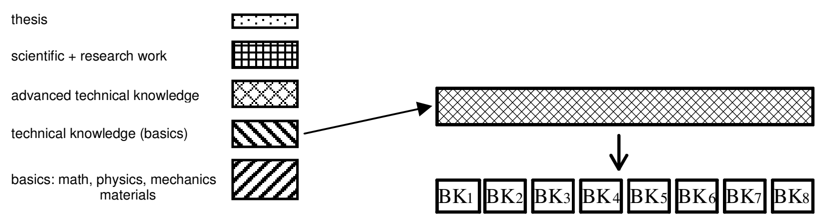


Figure 3: Modular architecture of the “basic technical knowledge” level

Figure 3 shows level two ”Basic technical knowledge” that can be divided into several modules. These modules are for example steel construction, hydraulics, and static. Within the steel module we might find sub-modules like design methods (BK1), plastic analysis (BK2), connections (BK3), trusses (BK4), stability (BK5), etc.

Usually we find a common architecture of civil engineering lectures. Each module will be processed within three defined steps as you can see in figure 4. The presentation of the course content will be done in a mono directional *lecture* by the professor. After this the content will be practiced in an *instructed exercise*. There standard problems will by processed by the student under supervision and with help of the lecturer. This usually happens in a lecture hall or room. Finally the learner gets *homework* to practice the transfer of his new knowledge to other problems. This homework will be made by the learner autonomous without instruction and might be marked. The sequence of lecture, instructed exercise and homework leads to a vertical linked structure. After the end of one element the next one will start again with a lecture. A horizontal connection between different modules is rare.

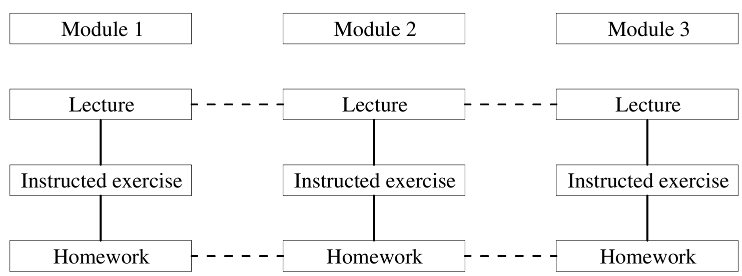


Figure 4: Structure of vertical and horizontal connections between respectively within modules

Analyzing the traditional set up of the module arrangement is necessary to find out whether this can be used in a new eLearning setting. A new structure may be suited better for eLearning courses.

Within the basic technical knowledge “connections” is a sub-module of the module “steel construction”. This sub-module can be divided into the sub-sub-modules “bolts”, “bending resistant joint”, “pin-joints”, “welded joint” etc.
The definitions of additional modules and the connections apply also for the sub-modules. Below the term module will be used for modules as well as sub-module (compare figure 5).

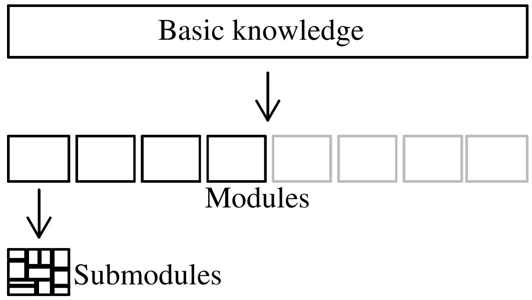
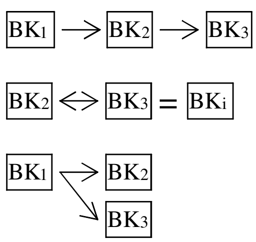


Figure 5: Splitting into modules and sub-modules

We are interested in the allocation of the sub-modules within a module. Which dependencies exist between the sub-modules? Are there sub-modules which are independent from others? All independent sub-modules are equivalent. If these modules do not constitute a basis for other modules, they can be described self-sufficient and isolated. If they are the basis of other modules, they can be called primary-independent. If two modules depend from each other, it is a signal that the arrangement of modules was selected too finely. These two modules have to be transformed to one module.

Figure 6 presents these dependencies.



BK3 depends on BK2, BK2 depends on BK1

BK2 and BK3 depend on each other. A new module BK_i has to be built

BK1 forms the basis for BK2 and BK3

Figure 6: Dependencies of Modules

All modules together form a network. This network includes different connections among the modules. These connections can be compulsory according to the modules dependencies. Independent respectively free connections can be set if textual coherences exist. Two different extremes can be developed. Making a linked network of self-sufficient modules leads to a maximum number **z** of links.

$$z = \sum_{i=1}^{n-1} i$$

If only dependent modules exist a linear network with z-1 links will be developed.

Usually a mixture of both extremes will occur. Linear parts can exist within the whole network. They control the direction of the learning path within the network. The intensity of linearity depends on the textual content (objective part) and on the module definition by the author’s arrangement (subjective part).

If many modules form the basis for a single module and furthermore this single module is the only basis for additional modules, this single module is called a bottleneck module. It should be analyzed whether it is possible to divide the bottleneck module into several modules.

Analyzing single modules particularly, each module may contain the three levels again:

- Basics (B)
- Basic technical knowledge (BK)
- Scientific work and research (SR)

The basic technical knowledge (BK) is the content which is needed to acquire the total knowledge of the lecture. In addition we have “scientific work and research (SR)”. SR is not strongly connected to the basic knowledge. Further information in addition to the BK will be generated by means of scientific methods. To get the basic knowledge the scientific work and research is not essential.

Consequently single modules have these three levels. The basics are required in the traditional lecture. To minimize the cognitive burden, scientific work and research will be rarely applied in the lecture. If the modules are transported in an eLearning setting, basics and basic technical knowledge can be realized easily. The learner can use these further resources ad libitum.

Which steps (lecture, instructed exercise, homework) can be transferred into an eLearning setting? Beyond all doubt the lecture with its mono directional communications-path can be transported into an eLearning application. Developing the instructed exercise into an eLearning setting, might lead to problems. The intended bidirectional communication between expert and learner can be achieved in an asynchronous eLearning setting only with much effort. Media like forum and email allow communication. Waiting a long time for respond can be felt demotivating. Computer generated answers produce mechanical suggested solutions for common mistakes and FAQs of the learner but not all possible mistakes can be matched. Problem formulations which require engineering sense, cannot be abutted on technical systems. Furthermore questions regarding the content from the learner cannot be answered systematical. The classical format of the instructed exercise cannot be transformed into an eLearning setting. Instead a sub-modular, quick computer generated knowledge check can be done. Worked examples consolidate the knowledge and prepare the learner in front of the instructed exercise.

In contrast communication problems will not appear in the homework. Here problems have to be solved without external help. Yet arising problems can be solved with the help of an expert. The expert leads the learner to solve the problem himself. Since more time is given for the preparation of homework more time is available for an asynchronous form of communication. The processing of homework in groups can be assembled by collaborative applications and the work can be monitored in real time by an expert. The expert can instruct the group or may watch only.

A combination of eLearning and traditional lectures in a blended learning unit for each module results in a sub-modular network. The instructed exercises can be enhanced with multiple choice questions and worked examples given via www to form the second step. The last step includes the homework in a traditional setting or in a collaborative online version.

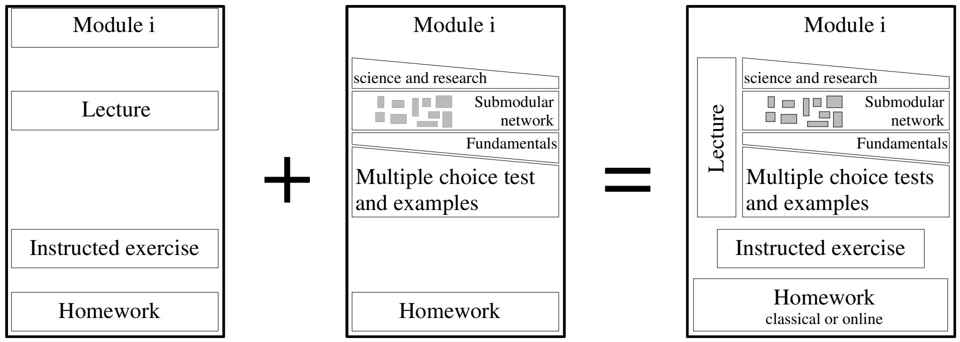


Figure 7: Traditional lecture, eLearning ambience and blended eLearning setting

Figure 7 shows an overview of the resulting blended eLearning setting.

Modular network construction

Regarding these guidelines for the module attributes the author is able to define the content. The content can be developed modularized and the dependencies can be defined. The author decides the primary quality of the network at his own discretion. One way is to produce a strictly linear network with much strong dependencies. Another way is to produce a network with lots of weak dependencies leading to a flat network.

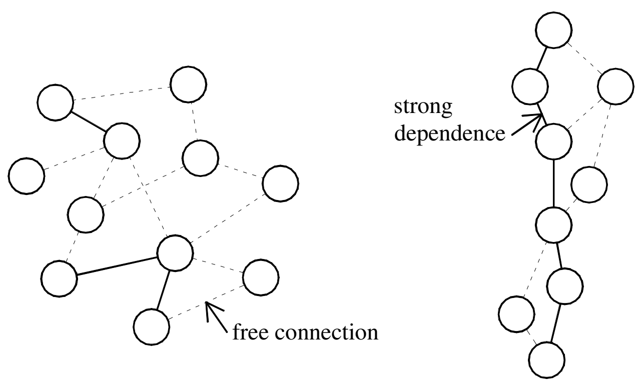


Figure 8: Plane network versus rigorous linear network

A plane network is a very similar platform with equivalent modules. The modules are linked by free connections. The learner can explore the network in compliance with his wishes. Its disadvantages are the stepwise loss of overview. In this case the network is restricted appropriate to novice learners. Advanced learners with a basic overview are appropriate to navigate. They can enlarge their abilities. Furthermore they can choose their field of interest and explore their knowledge in subareas of the network. This type of network develops scientific and research processing as an important meta-competence (compare figure 8).

A rigorous linear network with much strong dependence can give a good overview. Hence this type of network is appropriate to novice learners. They can explore linearly the network. Only a small part gives an open learning session and ascribes directly to a linear dependent path.

Educational objective taxonomy

To constitute the educational objectives it is indispensable to know the required competences of the learner. Is the learners a novice, advanced or an expert? Will he enter unknown territory or is he already acquainted with the content? Based on the university situation it is standard, that the learner's knowledge is still rudimentary. Normally the novice learner will be faced the first time with the content. The author has to decide which educational objective the learner should get after he listened to the lecture, respectively the eLearning session, after the instructed exercise and after finishing the homework. To decide this it is helpful to take the cognitive educational objective taxonomies by Melezinek[2].

Level 1	Knowledge
Level 2	Apprehension
Level 3	Application
Level 4	Analysis
Level 5	Synthesis
Level 6	Appraisement

These categories are strictly hierarchic, starting at level 1 and raising to complex level 6. A non representative survey addicted the following allocation. The survey results are shown in figure 9.

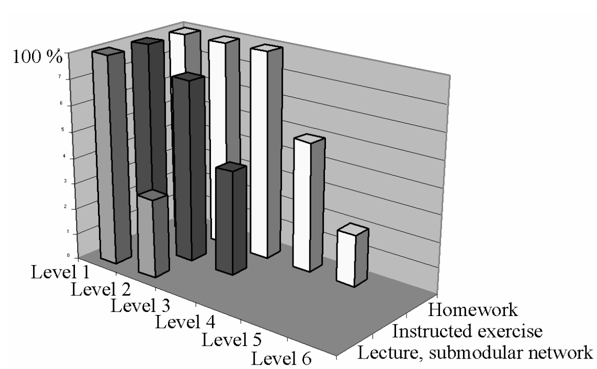


Figure 9: survey result

The interviewed experts had to estimate the educational objective level that novice learners will reach after revising the three steps of a classical learning setting in the basic knowledge area.

The expectations are that novice learner with no basics will reach educational objective level 1 after attending the lecture, respectively the eLearning network. After the instructed exercise the learner will reach level 2, respectively level 3 by opinion of 50% of the interviewed experts. By completing the homework the learner will reach level 3 to level 4 by 50% of the experts. It is not anticipated that the learner will reach level 5 "synthesis", nor level 6 “appraisement”. These two upper levels can be reached only when the learner has taken more modules and gets an acceptable overview about the complete content. After that the learner can compare different modules and prove the textual plausibility.

As mentioned above a linear network is advised for novice learners. They are guided through the process of learning and get a better overview of the textual content. But also the free flat network has its advantages. The learner can practice open learning settings. Beneath textual content the methods of learning will be improved. Presenting novice learners a plane network assumes that the learner is acquainted with opened learning settings and the process of learning is not disabled by loosing the overview.

Software

To realize the above described blended eLearning setting it is essential to have a flexible as well as powerful software application. An open source Wiki software is used as the content management system. Superficial Wiki engines are any linked websites. Contrary to common websites the Wiki sites are constructed dynamically. The content is not connected to the style and the page format. The content is saved in a database. The database system allows several users, developing content, reading and writing within the structure as well as working collaborative in texts. Registered user or user groups can be defined and have different authorizations. The management of the user rights will be done by the administrator (normally the author). It is possible to contain different media types (video, audio, picture) set external links and include several extensions and applications.

To use the special open source software MediaWiki has many advantages. MediaWiki is a freeware Wiki engine used to build the well known cyclopedia Wikipedia. The front-end of the module beam form the basic knowledge steel construction is shown in figure 10. To manage and save the data the relational database system MySQL is preferred.

Figure 10: Front-end of beam module

The advantages of MediaWiki are that it allows to generate mathematical functions as complex as possible. Several media types can be included. No skills in web specific computer languages are required. Furthermore the open source code of the application enables to rebuild the software to the user’s wishes. The accesses to the database are logged and saved on the server. The reasons for using the Wiki engine are the variability and sophisticated code.

Usertracking

To report the logfile score a server sided analysis is needed. It is also of great importance to log and save the client-side clickstream. The Wiki software is a web browser controlled application. Current web browsers allow several operations. It is possible to work in different tabulators (tabs). The browser based data caching allows returning to prior areas. Frequently requested content may be fetched by intermediary server and can be loaded from this actual source.
These three client dependent attributes can not be allocated by the source server and saved into the logfile.

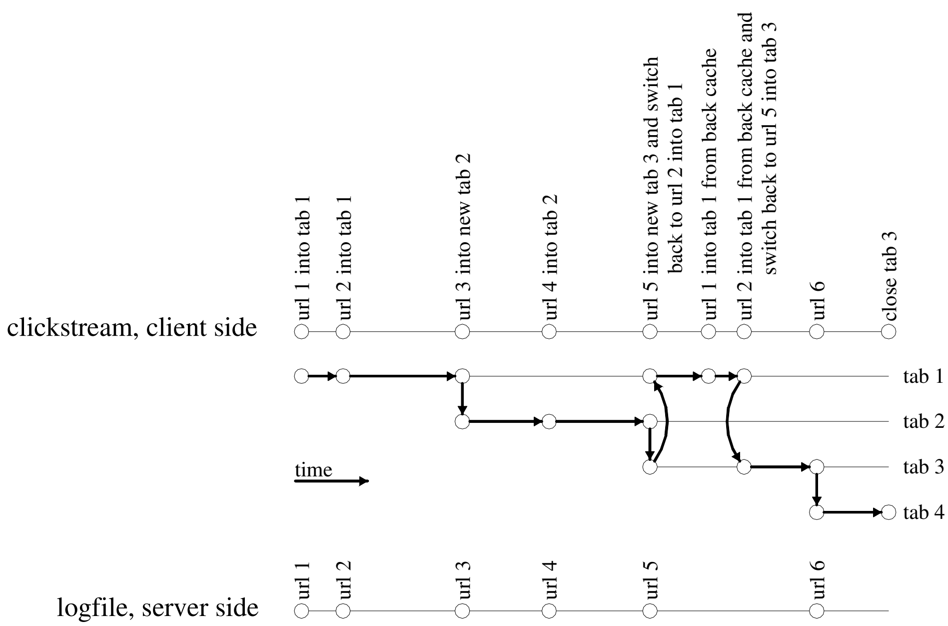


Figure 11: Server side logfile versus client side clickstream

Figure 11 shows the server side and client side logged data from a sixfold webpage. Whereas the server logs only fetches six URL's, the client side clickstream supplies considerably more information. The disability of the server to capture client side clickstream events necessitates to record this immediately from the client. Since the Wiki-Engine is a browser based software, the clickstream will be directly recorded in the browser. As common browsers do not save the user's attributes it is required to develop a special browser extension that monitors and saves the data that is needed. Here as well an existing resource can be used (clickstream recorder CSR[3]). On the client's side also an open source project software, an extension for the well known Mozilla based Firefox browser, will be used. The extension is able to monitor and save the timed data needed and send these to a defined server. Since the extension has to be installed and also privacy data will be saved and send, the user have to be informed about the extension and its attributes very detailed. A user who feels in danger using an application, will not use it. Saving only the data needed without monitoring private surfing attributes it is convenient to bundle another browser together with the extension and present this to the learner. The detailed data received by the extension is shown in the following list of figure 12.

field	description
<set♯>	events are numbered consecutively
<logtype>	either `server` or `client`
<time>	time of event
<CSRUserId>	unique for every user
<eventType>	one of the following:
	DocumentRequestStarted/Complete/Cancelled
	HistoryGoForward/GoBackward/Refresh
	linkClick
	newTabSelected/Inserted
	newWinSelected
	CSRStopped
<URL>	document location associated with the event
<windowId>	current window ID
<tabId>	current tab ID
<...>	various custom fields

Figure 12: Extension log file details[3]

The CSRUserId is the accidental personalized identification code allocated by the extension. The CSRUserId creates the coherency between the anonymous learner, the visited URL and the according time. Thereby it is the demand to allocate the difference of time between last actual URL and the accessed URL one step earlier.

$$\Delta t_i = U_i - U_{i-1} \qquad \text{i = number of URL}$$

This differential time describes the time required to acquire the content of the called URL$_i$. In consequence we get an array of differential time and URL personalized for each user. Another advantage of the extension is the coherence between the URL and the actual opened browser window (windowId), respectively the actual active browser tab (tabId). In this way the differential time of URL's within one window / tab is build by a new array.

$$\Delta t_{i.j} = U_{i,j} - U_{i-1,j} \qquad \text{i = number of URL, j = number of tab}$$

Besides the differential time and the URL coherence the extension monitors information about using the backward- forward button. Furthermore using other application within the browser will be recorded, for example, flash-animations, downloaded video and audio files. Using several data analyzing-algorithms the learning path of the user can be rebuild.

Digital – personal feedback loop

After detecting the temporal behavior of the learner by the browser extension, the path gone by the learner through the network can be reproduced. The effective residence time at one certain website respectively sub-module can be acquired. Furthermore the chronology of page demands is available. The whole time history of the learning path can be reproduced. If an amount z of learners uses the network, z independent learning paths are obtained. Now it is possible to analyze how many paths ϑ are equivalent. It has to be determined at which ratio $\xi=\vartheta/z$ a part of a learning path will be characterized as a main learning path. Both the path and the residence time can be visualized. Figure 13 shows in left part the visualized learning path. The bolder lines show that more learners have gone these paths. The right part shows the residence time. The darker the dots are the longer was the residence time. Furthermore figure 13 shows exemplarily that there is no correlation between the two attributes. The learning path might be used very rarely but the residence time might still be very long.

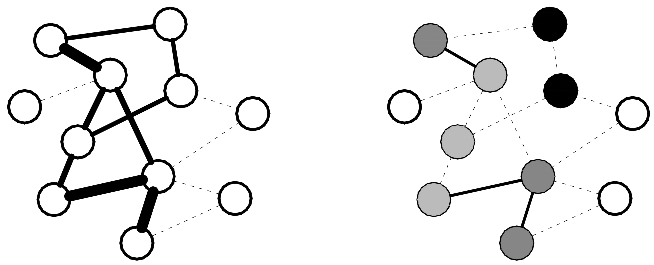


Figure 13: Learning path and residence time

Also both the resulting main learning path as well as a long residence time does not predicate anything about the effective condition of learning nor about potential problems. The only information received is the path and the time. But these can be indicators for possible hotspots that have to be attended. If one single learner stays for a long time at one module the danger for a mistaken explanation is very high. For example an opened tab / windows while quitting the computer simulates a long processing. Compared with this if a lot of learners resist a long time at one sub-module indicates a problem at this part. For this the author has to set a range of sub-modules. The number of words, pictures, formulas or media files has to be included in the estimated residence time. Also it is obligate to assess the subjective residence time. The author has to appoint how difficult the textual content of the sub-module is. For this a correction factor can be used. Multiply the residence time with the factor you get a validated residence time. Thus all the times are comparable.

In the same way the learning path can be validated. Fixed dependent connections will be used very often. Free independent connections will be used very rare. Hence the correction factor will be used.

The validated residence time and learning path show the hotspots of the network. Yet the author gets only digital feedback. By personal evaluation the results of the feedback can be transformed into a feedback loop. The hotspots give information about important sub-modules by analyzing the time and the path. This information can be entered into the classical lecture of the blended learning setting or the network can be updated.

The evolution of the network ends in optimized sub-modules respectively in improved connections. For example a long residence time requires faithful analyzing of the content. Is it too difficult to understand? Is the content badly developed for the novice learner? A partition of the sub-module into several sub-modules might be helpful.

Updating the allocation of the connections and the configuration of the sub-modules respectively the quantity of the sub-modules describes an evolutional step of the whole eLearning setting. For prospective groups of learners this updated setting has a higher level of quality. But this raise of quality applies only for the average learner. Learners at the upper and the lower end of the groups are not involved into this process.

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