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Zuerst erschienen in:
Proceedings of E-Learn 2006, World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education : October 13.-17., 2006, Waikiki Beach, Honolulu / T. Reeves & S. Yamashita (Eds.). Chesapeake, VA: AACE, 2006. ISBN 1-880094-60-6
S. 1611-1619
Referenz-Link EdITLib:
http://www.editlib.org/index.cfm?fuseaction=Reader.ViewAbstract&paper_id=23943

Managing Academic Education through Dynamic Storyboarding

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Abstract: Complex long term learning activities may be exhausting, tiring and sometimes even frustrating. In high level education such as university studies, there is a system of offers, rules, requests and prerequisites, which need to be matched with students' needs and desires. University students need assistance in the jungle of opportunities and limitations at today's universities. Here, we employ our formerly developed storyboard concept to face this problem and introduce a storyboard to develop, maintain, and evaluate academic education. Storyboarding is based on the idea of formally representing, processing, evaluating and refining didactic knowledge. It is more powerful in managing education than general AI knowledge representations such as frames, because the syntax of storyboards is driven by the particular nature of didactic knowledge. The concept is a supplement to the educational system (called Dynamic Learning Needs Reflection System: DLNRS) of the School of Information Environment of Tokyo Denki University, Japan. Concretely speaking, the didactic knowledge of DLNRS can be represented by storyboard and used for supporting dynamic learning activities of students.

Introduction

University studies are characterized by a high degree of flexibility with respect to the subjects to be included. On the other hand, there is a complex system of rules, requests and prerequisites that have to be respected to finish a study with success in terms of the knowledge and skill gain as well as its match with the individual needs and desires. Both the flexibility and the complexity of regulations increase during the study period enormously.

At least in the authors' countries, university studies suffer from a deficiency of clarity and an unacceptably high number of students fail because of regulations which they could not meet or even haven't been known to them. Avoiding the resulting frustration is one objective of introducing the storyboards. University students do need assistance in the jungle of opportunities and limitations at today's universities. Here, the advantage of flexibility turns out to be a sticking point. To really enjoy this flexibility and utilize it for the students' needs without a risk of not meeting requirements increases the students' motivation, which is the other objective of the proposed storyboard application. Qualified guidance needs adaptation, i.e. a certain dynamics with respect to varying needs, context conditions, and the students' educational history.

To face this problem, an education system, which we currently call *Dynamic Learning Needs Reflection System* (DLNRS) has been developed and introduced at the School of Information Environment of Tokyo Denki University (TDU) (Dohi & Nakamura, 2003).

The objective of the DLNRS is to keep and increase the students' motivation through clarifying and dynamically reflecting students' learning needs by themselves. The system is characterized by

- the abolition of the traditional rigid academic year,
- the introduction of prerequisite conditions,
- the displacement of a fixed charge per year by a subject-oriented paying system, and
- a Grade Point Average (GPA) system to rate the learning results and to derive appropriate consequences for the upcoming educational process schedule at TDU.

At a first view, there seem to be some parallels to the European Bologna Process of matching European systems of higher education. The Bologna Declaration (Bologna, 1999) signed 1999 by 29 European countries, requests the introduction of a Credit Point system. However, there are basic differences: (1) Its objective is the promotion of a (European-) wide student mobility by accepting Credit Point gained at any participating university. (2) The Credit Points do not exclusively reflect a student's level of topical skills. Instead, they rather quantify the workload achieved by the student.

As shown in (Dohi & Nakamura, 2003) the introduction was revolutionary and a big success. In a questionnaire, which has been filled out by 203 students, almost 90% expressed that the DLNRS is very understandable and useful for both creating class schedules and making a long term graduation timetable. However, the understanding level of the prerequisite conditions was about 60%. Thus, "the method of displaying the prerequisite condition needs to be improved." (Dohi & Nakamura, 2003)

To illustrate the dependence in-between the subjects and courses as well as to propose useful and efficient timetables with respect to the students' needs, the storyboard concept (Jantke & Knauf, 2005) is appropriate.

Although it was motivated by the upcoming opportunities and risks by the introduction of e-learning systems, its reach goes far beyond the limits of (current) e-learning systems. The concept is simple as general and allows modeling the didactic of any learning activities. The modeling concepts are standard: annotated graphs. Thus, storyboarding is a way to explicitly represent, promote, evaluate, and refine the didactic design of learning activities.

Moreover, it is a basis to acquire didactic knowledge by analyzing the design of successful learning. Again, storyboards model the didactic behind learning in general and provide appropriate paths in the (system of nested) graphs depending on different students needs, i.e. not the particular students are the subject of modeling.

The present paper is a contribution towards considering learning in a wider context than just a particular course or subject. Generally, learning activities need to be composed and designed at different levels. A fine grained level is the design of a lesson or - even finer - the discussion of a particular problem. The larger the scope of learning is the more human activities are involved including the management of comprehensive learning activities. By adopting the concept for a complete university study, the management of the study becomes assessable to evaluation and refinement, i.e. quality assurance.

The paper is organized as follows. Section 2 describes the DLNRS as successfully introduced at the School of Information Environment TDU. Section 3 is an introduction to the storyboard concept as developed so far. Section 4 introduces a concept to adopt the storyboard concept to support the development of class schedules and long term graduation timetables for effective and target-oriented university studies. Finally, the suggested approach is summarized, conclusions are derived and potential benefits are sketched.

Dynamic Learning Needs Reflection System

The DLNRS (Dohi & Nakamura, 2003) primarily aims at promoting the students' motivation by creating their own graduation time lines. This is a way to develop a spirit of independence, to keep up with globalization, and to foster a lively imagination. Key features of DLNRS are as follows:

1. **Abolition of the traditional rigid academic year**
   There is no academic year with fixed courses and a fixed fee. Instead, there is a semester-based course system with a tuition for each subject. Besides the prerequisites there is no rule when a particular course has to be attended. Thus, the students are able to study at their own adaptive paces.

2. **Abolition of mandatory subjects**
   Specific mandatory subjects have been replaced by the system of prerequisite conditions. These conditions are expressed in two forms (1) subjects that have to be learnt before and (2) subjects that are recommended to be learnt before. Both is formally checkable by considering the Grade Points received in these subjects.

3. **Displacement of a fixed charge per year by a subject-oriented paying system**
   Students pay a subject-oriented fee according to the number of units of the subject. Therefore, they carefully check their learning needs to pick out the right subjects to achieve their academic goal. Furthermore, it motivates to make a maximum effort to take the subject with respect to the money invested.

4. **Class period length**
   The usual length of a class is cut down from 90 min to classes of 50 and 75 *min*. Typically, a subject is taught in 3 units either as $3 \times 50\,min$ or as $2 \times 75\,min$ a week. The intended effect is that students will be able to concentrate the entire length of a class.

5. **Grade Point Average (GPA)**
   This is a system to rate the learning results and to derive appropriate consequences for the upcoming educational process schedule. The GPA of a course is

$$GPA = \frac{\sum_{i=1}^{n} u_i g_i}{\sum_{i=1}^{n} r_i}$$

with

- g_i being the points earned for a particular course,
- u_i being the number of units of this course,
- r_i being the number of units the student registered for in this course, and
- n being the number of courses in the semester.

The number of points per course ranges from 4 (> 80%) down to 0 (< 60%). The intention of this measure is that the maximum number n_{max} of units a student can register for is controlled by the GPA of the previous semester:

$$n_{\max} = \begin{cases} 25 & ,if \quad GPA \geq 3.0 \\ 12 & ,if \quad GPA \leq 1.0 \end{cases}$$

Table 1: Unit composition regulation for graduation

Field of the subjects	*units*
Introduction to SIE, Computer Literacy	*2*
Literal Arts related subjects	*40*
Major subjects	*60*
Other subjects	*22*
Σ	*124*

The introduction of the DLNRS at the school of Information Environment is supported by (1) a *Curriculum Planning Class*, which aims at developing an individual curriculum for each student that meets his needs and desires and (2) a *Workshop*, which aims at developing an ambience of mutual trust between the professors and students.

Since the relationships between the prerequisite conditions, the GPA and other aspects are difficult to overview, the development of class schedules and long term graduation timetables is a challenging task. As an example for "other aspects", there is a regulation for the composition of units for graduation as shown in Table 1.

So a Dynamic Syllabus system has been developed, which supports the students in this complex task in a four step process, (1) *acquisition of student data* (model course, field after graduation, career goal, student's preferences), (2) *selection of subjects*, (3) *simulation of the schedule*, and (4) *registration for the courses*. Steps (3) and (4) from a repeated process until a satisfactory solution is found, which meets all requirements and regulations.

For each subject, the Dynamic Syllabus system provides the number of units, the particular syllabus of this course (in an extra window, if clicked), and information about the prerequisites. However, the composition of a class schedule is a complex process of repeated prototyping and simulation with the Dynamic Syllabus system. The DLNRS is just one possible requirement list that is fixed at TDU. Of course, the storyboard idea can implement any other requirement list set by the university.

Our idea to improve this situation is to illustrate the interdependence of the subjects in a storyboard. This is an appropriate way to receive an overview about the prerequisite conditions of each subject. With a view to future trends, this approach might become consistent with the representation of the subjects particular curriculum including its didactics. Thus, a storyboard presentation here forms a top-level layer of nested storyboards for a complete academic graduation process.

Storyboards

The storyboard concept (Jantke & Knauf, 2005) is built upon standard concepts which enjoy an appealing visual appearance: graphs. Storyboards are defined as follows:

> *A storyboard is a tree of directed graphs with annotated nodes and annotated edges. Nodes are scenes or episodes; scenes denote leaves and episodes denote a sub-graph. Edges specify transitions between nodes. Nodes have (mandatory) key annotations and may have (voluntary) free annotations; edges may have (voluntary) free annotations.*

A storyboard is interpreted as follows:

1. *Scenes* denote a non-decomposable element of a learning activity, which can be implemented in any way: It can be the presentation of some (media) document, the informal description of the activity (e.g. 'an oral discussion about pros and cons of the US election system, moderated by the teacher'), and anything else. There is no formalism at and below the scene level.
2. *Episodes* denote a sub-graph.
3. *Edges* denote transitions between nodes.
4. *Key annotations* specify actors and locations; depending on the application, more key annotations may be defined.
5. *Free annotations* can specify whatever the Storyboard author wants the user to know: didactic intentions, useful methods, necessary equipment, and so on.
6. Both key and free annotations to episodes are inherited to each node of the related super-graph.

In fact, the storyboard is a knowledge representation for applied didactic knowledge and thus, a firm base for processing, evaluating and refining this knowledge. For this purpose, it is more powerful in managing education than more general knowledge representation concepts such as frames, because some particular semantic of didactics (like the key annotations) is reflected in the syntax of nodes and edges.

Storyboards share some features with other knowledge representations:

(1) Each element of the hierarchy is a graph and thus, a semantic network.

(2) The hierarchy is like the one with Frames and OO-representations and characterized by a hierarchy and a top-down inheritance.

However, the storyboard concept is much more expressive to represent educational knowledge:

(1) Semantic networks are not appropriate for representing procedural knowledge such as sequences, conditional jumps or loops, but elements like these are mainly necessary for representing didactics.

(2) Frame hierarchies are intended to represent knowledge like *is-a* inheritance (class and instance), part-of aggregation, and so on. This does not apply to storyboard hierarchies.

Particular languages that are developed for representing educational knowledge such as the Educational Modeling Languages (EML) (Rawlings et al. 2002) like OUN-IML (CEN/ISSS 2003) (Marino 2005) or Instructional Modeling Language Learning design IMS-LD (CEN/ISSS 2003) (Marino 2005) and MISA (Paquette 2003)

- enjoy, on the one hand, the benefit to be created for this particular use and thus, to be quite expressive, but
- suffer, on the other hand, from not being easy to use by non-IT experts.

Error! Reference source not found. shows an example storyboard on a last author's paper. The representation as a graph (instead of a linear sequence of sections) reflects the fact that different readers trace the paper in different manners according to their particular interests, prerequisites, a current situation (like being under time pressure), and other circumstances. For example,

- members of our research group will skip the sections 1 and 2, because they are already motivated and familiar with the concept,
- reviewers of this paper, on the other hand, will (hopefully) read the complete paper, but they might skip the Acknowledgement section, because its content doesn't matter for their work.

So a storyboard can be traversed in different manners according to

- users' interests, objectives, and desires,

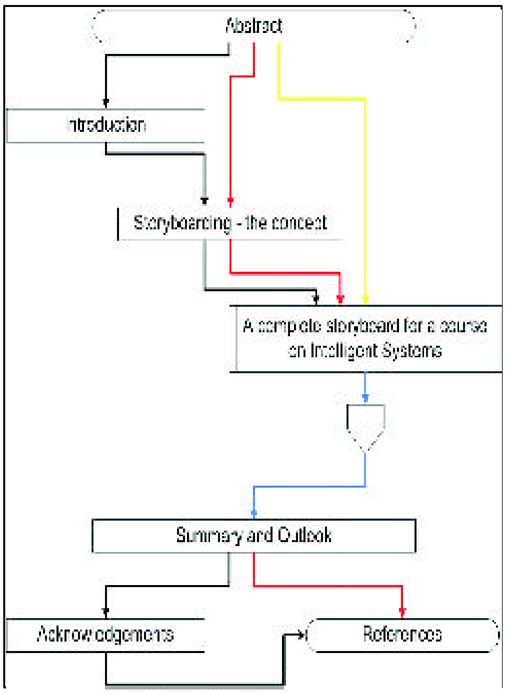


Figure 1: An exemplary Storyboard

- didactic preferences,
- the sequence of nodes (and other storyboards) visited before (i.e. according to the educational history),
- available resources (like time, money, equipment to present material, and so on), and
- other application driven circumstances.

Towards more powerful tutorial knowledge representation features different from semantic networks or frames, storyboards are an adequate way to represent lows of educational scenarios such as DLNRS in a more simple and direct way hierarchically. Compared with traditional knowledge representation methods, storyboarding is more understandable and adjustable by humans, in particular in case of being implemented with a standard and easy to use tool like Microsoft™ Visio. Almost every topical expert is able to design, use and refine a storyboard representing the didactic design to learn his/her subject.

The concept can be further refined by numerous additions as listed below. Not all the following supplements are really necessary. Vice versa, some of the features may not be applied to particular storyboards. For high level storyboards as introduced here, free annotations don't apply.

Many of them are implicit in the general concept. We discuss those details only for the readers' convenience, to become a little more familiar with our ideas, aims and intuition. For building storyboards, we use Microsoft™ Visio. Readers may use any other appropriate tool.

1. Because those nodes that are called episodes may be expanded by sub-graphs, storyboards are hierarchically structured graphs by their nature.

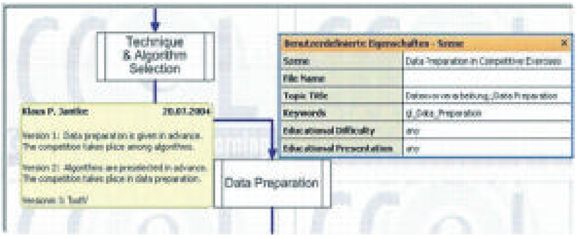


Figure 3: Annotations to an atomic scene

2. Comments to nodes and edges are intended to carry information about didactic. Goals are expressed and variants are sketched.
3. As far as it applies, educational meta data may be added.
4. Edges are colored to carry information about activation constraints and variants of their adaptive availability. Colors may have a fixed meaning.
5. Actors and locations inclusive those in the real world are assigned to elementary nodes only.
6. Certain scenes represent documents of different media types like pictures, videos, PDFs, Power Point slides, Excel Tables, and so on.

A wide-spread and easy-to-use standard tool such as Microsoft™ Visio supports the acceptance and use of the storyboard concept for many reasons such as the following ones:

- Knowledge or information sharing with data available in other formats like CAD, UML, BPM (Business process Management), XML, or Microsoft™ Office products such as Word or Excel is easy to implement. Therefore, the storyboards implemented in Visio have a high expandability. There is no need to re-write former documents or data of the educational system to integrate their knowledge into storyboards.
- The educational model can easily and visually created and modified by humans.
- The implementation, use, evaluation, and refinement of storyboards can be supported by computers using the opportunity to include macros in Visual Basic. Simple consistence checks, e.g. for counting or logical mistakes by human storyboard authors, can be implemented.

For illustration, Figure 2 shows a top level storyboard that has been designed by the last author for a course on Data Mining.

Figure 3shows the scene *Data Preparation* from the sub-graph behind the episode *Competitive Exercises* of this storyboard with a comment to an incoming edge (on the left) and the node *Data Preparation* (on the right). In a more detailed storyboard, this scene maybe turned into an episode and, thus, be further refined subsequently.

Storyboarding for e-learning is a process that might never end. One may always take a scene, declare it an episode and continue in-depth design. The sophistication of storyboards can go very far. The concept allows for deeply nested structures involving different forms of learning and permitting a large variety of alternatives. In our practice, discussions begin frequently with a top level storyboard of only about half a dozen nodes. Discussing their arrangement is a first step toward didactic design.

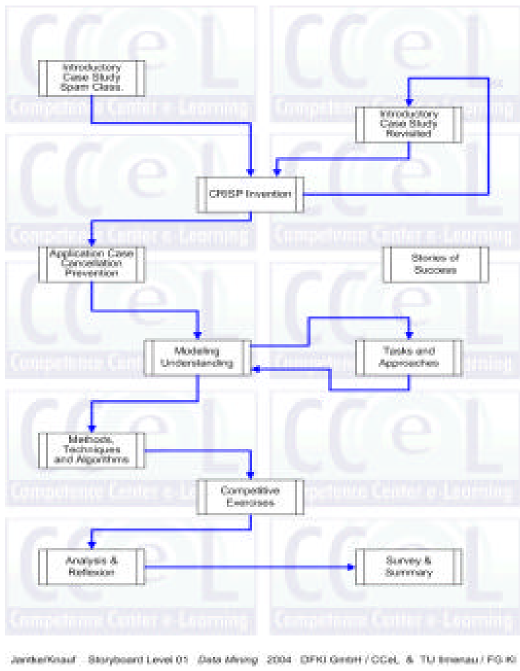


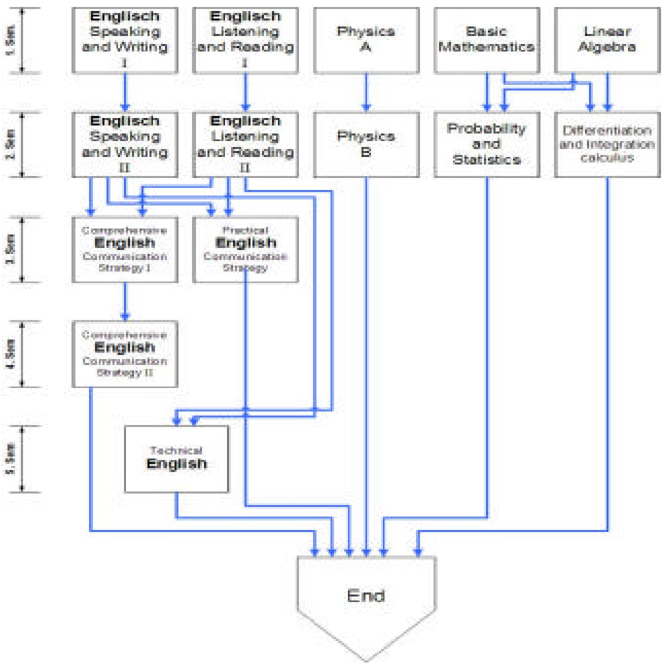
Figure 2: Storyboard of a course on Data Mining

Higher Level Storyboards for Academic Education

Using the DLNRS combined didactics or tutorial knowledge that is represented by storyboards, learning plans such as students' curriculum plans for getting their necessary academic carrier have the opportunity to be formally as well as visually checked, reasoned (generated), or dynamically verified and modified after each period of use.

More concretely, as a contribution towards storyboarding an academic graduation career we propose a storyboard, which contains subjects to teach as episodes and examinations to pass as scenes. The episodes need to be defined as sub-graphs by the subject matter professors. We understand this paper as a motivation to follow us towards a complex storyboard for a university study. But even at the top-level, some overview can be kept by nesting the storyboard graphs. This overview can not be provided by any printed document as commonly used today.

For illustration, Figure 4 shows the top level storyboard for the study of Information Environment at TDU. The rectangles with double vertical lines are episodes. The rectangles without them are scenes. Behind the episodes there an *Off-Page Reference* node, which marks the re-entry point when jumping back from the sub-graph that implements the episode. This study is very adaptable to the students needs, but the price for this enjoyable feature is a complex system of conditions to meet:



- The study can be performed in one of three courses for a specialized subject, namely (1) *Network Computing*, (2) *Advanced System Design*, and (3) *Media Human Environment Design*.
- Each course consists of around 60 units of major subjects recommended to learn and is composed of several cores. The *Advanced System Design* course, e.g., consists of the cores (2a) *Web Systems*, (2b) *Multi Media Systems*, and (2c) *Robotics*.
- Additionally, two general cores, namely 2 units of *Orientation* and 40 units of *General Cultural Subjects* (*Literal Arts* and related subjects) are a prerequisite to graduate.
- The nesting goes beyond that. In each core is a large number of 30-35 subjects. Some of the subjects belong to more than one core, others don't.

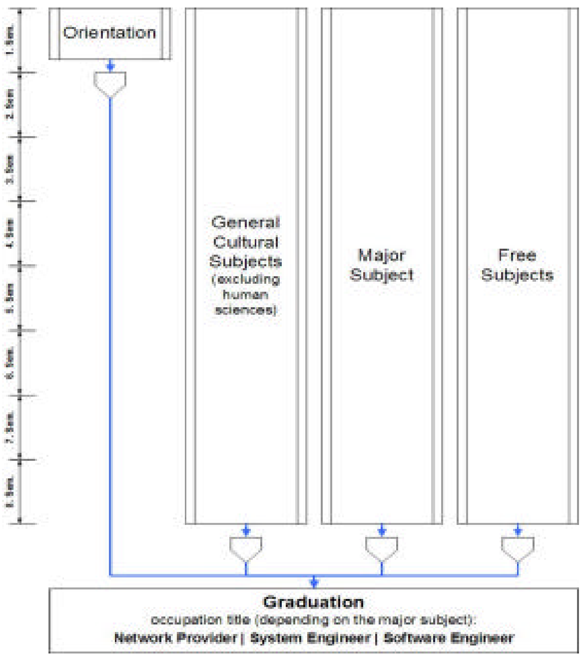


Figure 4: Top level storyboard

- Moreover, another 22 units of any other subject outside the selected course is requested to graduate.

Doesn't this situation call for a representation in nested structures?

Figure 5 shows the storyboard on *General Cultural Studies* exemplary. The semester axis on the left is just a recommendation. A directed edge denotes the prerequisite-relation between subjects. The *End* – node is an *Off-Page Reference* that serves as the node to jump back into the related super-graph by double clicking it.

Storyboards for academic education are very individual and dynamic. The composition of a plan not only depends on general regulations, but also on individual facts like (1) goals to meet (a position to reach, a company to serve, a individual talent to support, an amount of money to make), (2) pre-conditions to fulfill (a necessary pre-education, a requested level of success in preceding semesters or the school-leaving examinations, a necessary equipment, a certain language skill, an amount of resources like money or time), (3) talents to meet (to be creative, analytic, being endued with leading people, a certain level of sportiveness). In the undergraduate study of the TDU students, for example, there is the Grade Point System that limits the number of units to enroll for an upcoming semester (see above). Of course that narrows the storyboard for an upcoming semester.

To take the individuality and dynamics into account when composing a storyboard for academic education, issues like goals, pre-conditions and talents need to be formalized and associated to both the related episodes (as a key annotation) and the students. This opens the perspective to support the development of goal-driven individual storyboards by appropriate tools.

Summary and Outlook

In contrary to basic level education such as those in primary and secondary schools, academic education at universities is characterized by a large variety of opportunities to compose academic time lines and course schedules. Like at TDU students become more flexible in designing their study according to their needs, wishes, interests, and talents.

However, there is a system of requirements to meet and rules to follow to guarantee a certain level of academic quality. These rules are often complex and difficult to overview. A remarkable number of students fail by violating such regulations – often because of not knowing them. Students need assistance in this jungle of opportunities and limitations. A basic property of a qualified guidance is adaptability, i.e. a certain dynamics with respect to varying needs, context conditions, and the students' educational history. The basic benefit compared to any complete representation of rules is the overview by (1) nesting the graphs and (2) narrowing them individually according to the particular students' needs.

Currently, this and a similar system to support the Computer Science study at the Technical University Ilmenau are under construction and not used yet. In fact, the suggested approach is very general and can easily be adopted for any other university education. With the objectives of

Figure 5: General Cultural Subjects

- a software realization of *knowledge processing* (i.e. deductive inference on storyboards),
- evaluating storyboards by case-based validation technologies such as the one in (Knauf, Gonzalez & Abel, 2002)
- *machine learning* (i.e. the identification of didactic patterns by some sort of data mining and inductive inference),
- *knowledge refinement* by improving particular storyboards due to didactic insights that became explicit by storyboarding, and finally
- *knowledge engineering* by supporting the storyboard development with a toolbox of didactic patterns that are proven to be appropriate in former use,

the overall concept is currently under revision. Our upcoming work on this issue is as follows:

- A *short term objective* is, of course, promoting the development and use of this concept.
- After that, as a *medium term objective*, we plan to develop an evaluation concept for storyboards based on the learning results of the students as acquired from the final grade they achieve for the storyboarded courses as well as the students' specific comments in a questionnaire.
- Our *long term objective* is to identify typical didactic patterns of successful storyboards. Since the learning result of a particular student is associated to a particular path through the storyboard, we should be able to identify successful storyboards in general, but also successful paths within storyboards in particular. Through the use of Machine Learning methods, we finally might be able to find out what these successful storyboards respectively paths have in common and in which properties they differ from the less successful ones. Thus, we might be able to identify successful didactic patterns.

The latter is, in fact, the vision of knowledge discovery in didactics. By utilizing the didactic insights acquired by this approach for the upcoming storyboards, we intend to close the loop of the never ending storyboard development spiral.

Future long term research needs to be directed towards (1) a definition of (formally to check) criteria that allows the specification of individual goal-driven storyboards. In fact, this is very different in different cultures, countries, and universities. Therefore, we plan to do that prototypically for the *School of Information Environment* at TDU. Another focus is (2) including meta-knowledge to infer learning needs and meta-knowledge to infer learning desires, preferences and talents. The former meta-knowledge is useful for maintaining their resources according to the needs through having some prediction about upcoming students' learning needs. The latter is necessary not only for a need-oriented and effective planning at universities, but also for suggesting storyboards according to the students' desires.

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