Innovative Education Enabled by Knowledge Organization and IT: Goal-directed, Flexible, Individualized, Collaborative

Dagobert Soergel[1]

Abstract

This paper presents a design that harnesses the power of well-organized knowledge and of IT to transform the learning environment in higher education and enable new ways of learning for a changing population of students preparing for a changing world of work. Students would be empowered to pursue the learning goals and objectives they wish to achieve, using learning opportunities matched to their knowledge, cognitive abilities, learning style, motivation, physical abilities, and social skills. We envision a system with four components: ***(1) A well-structured interlinked multi-perspective, multi-source classification of concepts and skills used to specify learning goals and objectives*** *(what students should learn) and learning outcomes (what students did learn). This classification would be developed and maintained collaboratively from many sources (educational standards, faculty, students, etc.).* ***(2) A large database of learning opportunities / learning units,*** *from courses to small modules, including individual lectures, assignments, and exams. This database would support individualized programs of study leading to desired credentials or satisfying a desire for knowledge. Learning units would use many innovative ways of presentation and interaction. The same content would be available in many learning units for different kinds of students. Learning units would be indexed by learning objectives, prerequisites, and student characteristics to enable adaptive selection They would be interlinked in a knowledge graph to support exploration.* ***(3) Detailed tracking of learning outcomes for assessment****. A continuously updated mastery transcript lets each student track his or her progress towards a degree, a microcredential, or preparation for a certification exam. Mastery scores come from very detailed tracking of learning outcomes; for example, the score for an exam answer and the grade for an assignment with the same learning objective combine into one mastery score. Outcome assessments allow for alerts to advisers. They provide data on how well a learning unit supports achieving a learning objective by different kinds of students.* ***(4) An IT infrastructure*** *that supports collaborative work on the objectives classification; authoring learning units indexed to the classification; selection of and interaction with learning units; tracking for assessment; and accessing knowledge anywhere, commenting, and collaborating in a learning community.*

Keywords: *Transforming Higher Education, Goal-Directed Learning and Assessment, Taxonomy of Educational Objectives, Mastery Transcripts, Learning Units Adapted to Learner, IT Infrastructure, Characteristics, Powerful Knowledge;*

1. Introduction

We present a design that harnesses the power of well-organized knowledge and of IT to transform the learning environment in higher education and enable new ways of learning for a changing population of students preparing for a changing world of work. Students would be empowered to pursue the learning objectives they wish to achieve, using learning opportunities matched to their knowledge, cognitive abilities, learning style, motivation, physical abilities, and social skills.

Changes in society bring new types of students and many challenges to higher education:

- Providing 24/7 access;
- letting students learn on their own time;
- providing certificates that let students acquire just-in-time, just-what-is-needed information;
- assessment that captures and reports mastery of specific items of knowledge and skills;
- celebrating diversity by adapting materials to each student's background, configuration of abilities. and interests to unlock the potential of all students and close the opportunity gap resulting from inequalities in society;
- lowering cost while increasing quality.

[1] University at Buffalo, United States

To meet these challenges, we develop a vision and sketch a design in which learning goals and objectives drive the organization of learning with integrated assessment, still leaving room for student-directed inquiry. This ambitious vision becomes feasible and cost-effective through tools for intellectual work (mind tools), meaningful organization of knowledge, and IT infrastructure to

- facilitate the design of learning units **(**from seated or online courses to small modules, including individual lectures, assignments, and exams),
- deliver learning experiences,
- administer assessment.

We build on many ideas in the field: Competency-based education [1] [2], mastery transcripts (standards-based grading, performance assessment) [3], and microcredentials and badges. We advance these ideas and integrate them with a focus on higher education, resulting in the design of one comprehensive system with benefits of efficiency and scale. We do not know of an implementation of such a comprehensive system. For K-12, the Web-based *Kiddom* provides a database of assignments indexed to standards and manages standards-based grading [4].
We now discuss the four components of our design.

2. Multi-perspective classification of concepts & skills to define learning objectives

At the heart of our design is a multi-perspective, multi-source classification of knowledge items, concepts, understandings, competencies, skills, opinions, behaviors, habits, attitudes, and dispositions that is used to specify learning goals and objectives (what students should learn) and learning outcomes (what students did learn). This classification would be developed and maintained collaboratively from many sources (educational standards, faculty, students, and more). Competency-based education and mastery transcripts use highly focused fixed sets of learning objectives, such as the US Common Core Standards, content standards promulgated for schools, or professional certification standards. In contrast, we envision a large and diverse classification built from many sources by many stakeholders. In a university learning objectives can be set at every administrative level and with varying degrees of specificity, starting with broad objectives at the university level, going to increasingly more specific objective for decanal units, departments, degree programs, courses, specific sections of courses, and finally specific lectures, activities, assignments, and exam questions. The objectives for courses and below are often set by the instructor; these would be included in the comprehensive classification. Students should map out their individual learning objectives, considering the objectives of the program they attend, but adding objectives of their own. So learning objectives can be set by students, instructors, professional associations, accrediting bodies, employers, parents, politicians, theorists and philosophers of education. All of these would coexist under one big tent, not in isolation but arranged in multiple hierarchies with similar objectives linked to each other. The topical hierarchy is augmented through prerequisite relationships between learning objectives as required for proper sequencing of learning units in a learning path.

There are many external sources for such a classification. Here we give just a few examples.

- Bloom's *Taxonomy of education objectives or* the 2002 revision.
- The *Atlas of Science Literacy* (includes prerequisite relationships) [5] (Fig. 1)
- Competencies and skills tested on, for example, the GRE.
- Career competencies and skill profiles as specified by professional associations.
- Competencies and skills students must demonstrate to obtain certificates and badges.
- Any topical classification in an area of curricular interest.

Developing and maintaining such a classification requires software that

- allows for importing external hierarchies;
- supports collaborative creation and maintenance of a very large hierarchy;
- stores concept mappings;
- provides for personal and group spaces;
- tracks ownership of concepts and permissions;
- tracks sources and modification history for all pieces of information.

3. Highly indexed interlinked database of learning units

We envision a large database of learning opportunities / learning units, both internal and external, ranging in granularity from an entire degree program to smaller credential or badge programs, courses, individual lectures, assignments, exams, and individual slides. The same content would be available in several learning units for different kinds of students. Learning units would be indexed by learning objectives, prerequisites, and student characteristics to enable adaptive selection, matching appropriate learning units with students. Learning units would be interlinked in a knowledge graph to support exploration

Learning units should be designed using new insights into how students learn from psychology and brain science, the learning sciences, and evidence-based teaching as well as advances in information and knowledge organization and representation, human-computer interaction, and the science of building collaborative teams. Computer-based learning units can be offered to many students at low cost, as part of a seated course or in a completely online environment. If done well, they provide a superior learning experience, especially interactive learning where students truly engage individually or collaboratively.

This database would support individualized programs of study leading to desired credentials or satisfying a desire for knowledge. Give a student a learning path, a sequence of learning units / learning opportunities selected based on her profile and learning objectives, logically sequenced, and dynamically adapted using small quizzes and other data on the student's progress. The learning opportunities should support both individual and collaborative learning. Students could branch out from the learning path as they go through it.

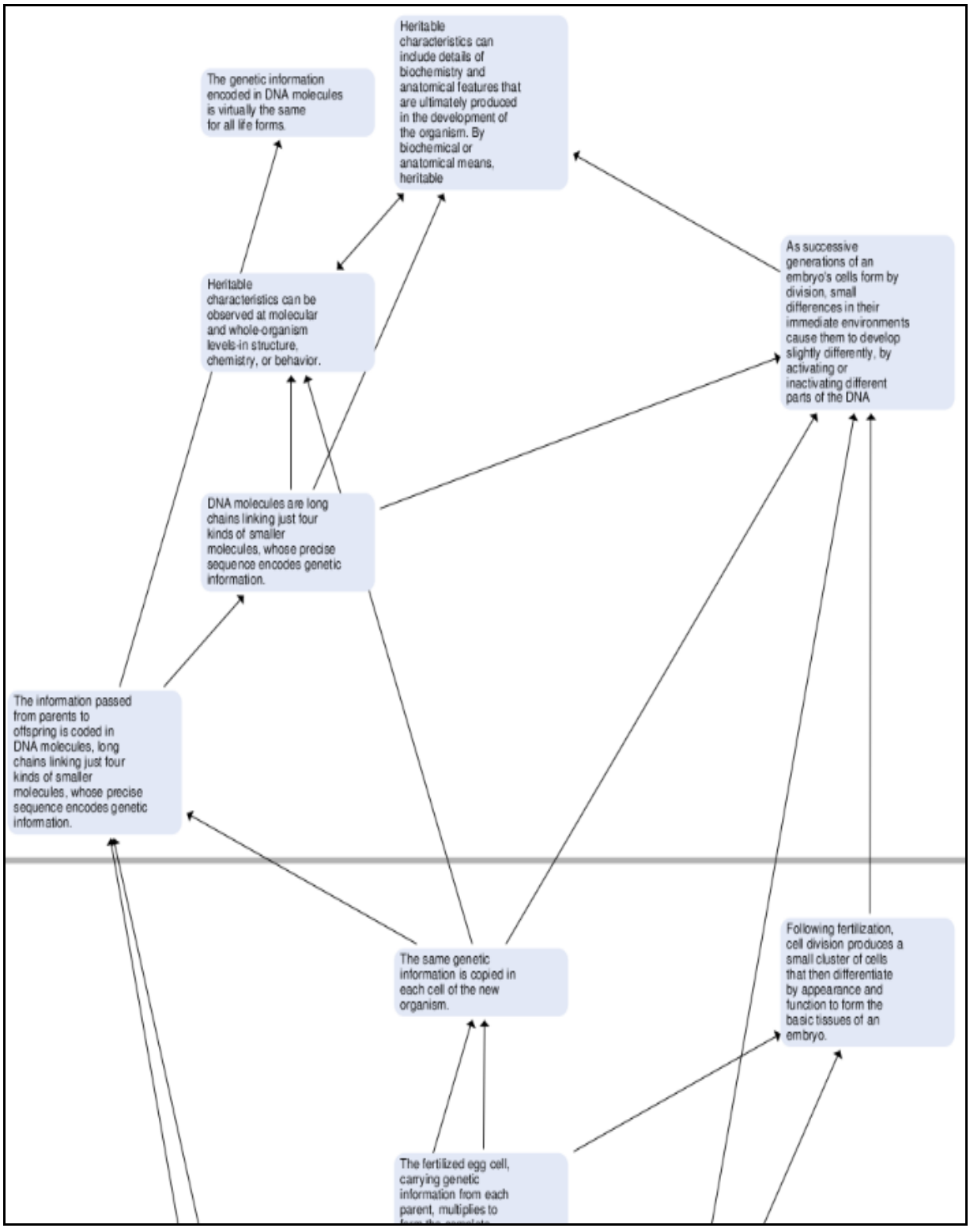

Figure 1.Example from a Learning Objective Classification.
Atlas of Science Literacy. Strand-Map Segment
Showing content units = learning objectives with prerequisite relationships

Making this work requires a system that lets faculty find, modify, and create learning units and lets students prepare class presentations and papers. This system needs to support

- authoring interactive learning units;
- rights management;
- social tagging, commenting, and review;
- powerful retrieval and the automatic construction of learning paths.

4. Detailed tracking of learning outcomes for feedback and credentials

This is a key element of our design. Mastery scores come from very detailed tracking of learning outcomes; for example, the score for an exam answer and the grade for an assignment with the same learning objective combine into one mastery score. A continuously updated mastery transcript

- lets each student track his or her progress towards a degree or preparation for a certification exam;
- allows alerts to advisers;
- allows checking whether a student has the prerequisites for a learning unit she wishes to take.

Assessments can be aggregated for a course (giving the instructor feedback on how the class does for each objective) and for an academic unit (any level). Assessments support analyzing how well a learning unit supports achieving a learning objective by different kinds of students.
A mastery transcript gives a score for each learning objective in a program of study based on all available evidence across all courses or other learning units the student has completed so far. Table 1 illustrates the process for combining evidence from a single course.

Table 1. Tracking Achievement of Student 15

Objective	Assgnmnt	Midterm question	Final question	Paper	Score
O2.2 Understand a general model of Information Retrieval	A1: **100**		FQ7b: **60**		75
O2.4 Be able to construct an Entity-Relationship data model	A6: **100**	MQ2:**50**		90	87
O6.4 Understand mark-up language			FQ6a: **80**	85	83

Each learning unit is indexed by its learning objective(s). The instructor records scores inside the system, producing the data in Table 1. The scoring formula gives more weight to the final and the paper. (When evidence comes from several courses, the latest course gets most weight.) The students gets a mastery transcript for the course and a letter grade derived through a weighted average score, some objectives being more important then others. Grading an assignment using a rubric follows the same process: The assignment is a learning unit, it is indexed with the rubric elements, which are all included in the large classification of objectives along with their definitions and possible values. The instructor records rubric scores in the system. The student receives the rubric scores and a grade. This is now supported by some learning management systems. To compute overall mastery scores, the system uses the rubric scores, not the assignment grade.
The mastery transcript upon completion of an entire program is far more informative for prospective employers than the traditional course transcript.
The process described would be far too laborious if done manually; it is feasible only if managed by a computer system.

5. IT infrastructure

Our approach depends on an ambitious integrated IT infrastructure that supports

- collaborative work on the objectives classification;
- authoring learning units indexed to the classification;
- selection of and interaction with learning units;
- tracking for assessment;
- accessing knowledge anywhere,
- commenting and collaborating in a learning community;
- full LMS functionality.

Collaboration is central for all components of the system, especially collaborative learning. It requires a powerful platform for communication and collaboration in the entire university community. This platform should be able to emulate the process of a group of students working on a problem and writing solution ideas on a blackboard.

6. Looking ahead

Working towards this vision rests on two pillars:

1 The university administration must provide the IT infrastructure.
2 The faculty must buy into the system based on voluntary participation respecting academic freedom.

To start somewhere, some functionality of the system could be provided through stand-alone software to be used by faculty individually.
Implementing our vision requires a large investment, but that investment promises large returns in making higher education less costly, more inclusive, and better for all.

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