HAW HAMBURG

CoKoMo

A Knowledge-Modell for Education

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INHALT

Our project CoKoMo provides a knowledge model for the BMBF project "meinBildungsraum" (the German National Platform for Education). It establishes a central interface between people and computer applications, capturing knowledge elements and their mutual semantic relationships. The model aims at providing the basis for current and future applications in the EduTech sector. This document describes why we see CoKoMo as a key technology in a future education economy and what needs to happen for this potential to be lifted.

HAND BRAKE PULLED IN THE GERMAN EDUCATIONAL PRODUCTION

Education in Germany is strongly oriented towards traditional values – it makes sense to be clear about this at the outset. Compared to the social-democratic or liberal education systems of the Scandinavian or Anglo-American countries, the conservative educational system of German origin relies on a traditional differentiation of teaching offers and bureaucratic regulation instead of market-based influence. The named educational systems are now competing with each other to stay ahead in production and value creation in a technological world. Shortage of skilled workers, lack of teachers, decreasing competencies of students in basic subjects and especially in STEM subjects outline the magnitude of the challenge today for the economic location Germany.

The Conservative Education State

Choosing such a problem-oriented perspective in the first paragraph serves to outline the following:

The conservative German education system is extremely ill-equipped to deliver innovative services.

It is not only a matter of solving a specific, for example, technical problem. We are asking here for a fundamental approach that enables an industry - educational production - to develop and market innovative, computer-based services.

This statement does not question the innovative power of today's commercial providers or those in the non-profit sector with their web portals, especially in the tutoring sector. From the perspective of the CoKoMo project, however, public education should not rely exclusively on isolated solutions with incompatible formats for learning objects and knowledge modeling - as it does today. What is needed instead is a fertile ground where many small and medium-sized enterprises (SMEs) can offer new, decentralized services for school and university education. And simultaneously facilitating transparent access to open-source content and algorithms. The fact that this has not beed addressed consistently has both economic and organizational reasons.

Taking the perspective of organizing of education, the question to be answered is: what measures can help to re-organize and release the handbrake towards a lively, decentralized, open EduTech market?

The Innovative Power of SMEs Lacks Traction

Providers in eLearning are successful today when they offer complete solutions for a specific problem - for example, tutoring for secondary school students in mathematics (for high schools in the state of Hamburg). And these offerings are often of very high quality. However, since learning content, analysis methods, teaching interventions, user experience, and individual learning levels are encapsulated in solitary products, exchange with the state education system and its institutions is often difficult and only works as a "one-way street" from the provider to the school. From CoKoMo's perspective, public education needs an open educational landscape.

This one-way-problem applies in a similar way to publishers of schoolbooks - the only significant market-driven elements in state educational production to date. However, IT services are likely to have a significantly greater impact.

Noe let's assume the economic aspects of this problem are manageable. Then the question remains: how can a start-up company be successful in the market without completely reinventing education?

A similar challenge has brought Germany a sustainable success story in a different context: the emergence of many SMEs in industrialization based on norms & standards. For this development, Germany established a framework of clearly defined company-interfaces in the early 20th century. This allowed goods and services such as screws and nuts (DIN EN ISO 225) or processes for quality management (DIN EN ISO 9000) to be exchanged smoothly between individuals and companies. A company that manufactures screws and nuts can sell them to many interested parties. Under the designation "Hexagon bolt with shaft DIN 931 A2, M 5 x 40," the customer and supplier then understand exactly the same thing.

From CoKoMo's perspective, the German education market lacks exactly these standardized interfaces to develop a partially market-driven and economically organized EduTech sector.

Standardization as „Enabler"

In CoKoMo, we started by elaborating a value network right at the beginning of the project: a network of stakeholders - existing as well as future ones - indicating the added value exchanged between them. And the analysis shows that a normative reference for what we colloquially call "knowledge," is a necessary pre-requisite for an open education market.

By "knowledge," we mean a clear understanding of a concrete learning objective. An example:

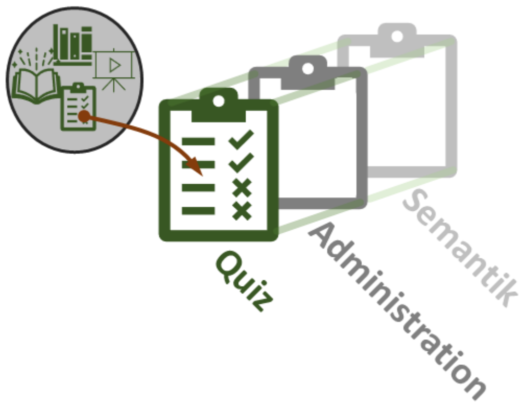


Figure 1:Metadata for learning objects

In a catalog of learning objects (videos, books, tests, etc.), is a quiz on the topic of "Quadratic Equation". In order for the learning object to be found and reused outside of a fixed context, it must be linked with machine-readable metadata on an administrative layer ("was created by," "is of type quiz," "is in Moodle XML format," etc.) and a semantic layer ("The quiz assesses the learning objective >I can solve quadratic equations with real-valued coefficients using the p-q formula.<").

For the administrative layer, there are de facto standards such as AMB, based on LRMI and schema.org, or approaches for de jure standards such as those in the German Standards Committee NA 043-01-36 AA "Learning Technologies" for ISO-IEC 19788-1.

What does not yet exist, or does not exist fittingly, are metadata standards for the semantic capture of knowledge elements. This is what CoKoMo provides.

Traditionally, semantics are conveyed through terms, such as "Quadratic Equations" in the example above. However, this informal and imprecise addressing of knowledge is rather inefficient in the context of computer applications.

Why a Standard for Knowledge is Needed

The search for a term - such as "Quadratic Equation" - yields content associated with the term by a search engine when searching the internet. In computer science, a collection of terms and their relationships to each other is called an "ontology", in the example above in its simplest form as a loose collection of terms.

The problem with terms begins with the inherent ambiguity when delineating the term from its neighbors. Does "Quadratic Equation" really mean the equation - as an equation in which the left side is a polynomial of second degree with real-valued coefficients and the right side is zero? Or does it refer to a specific solving method? Should a specific solving method only be mentioned or applied? And if terms - as mentioned above - stand alone, there is also no context from which one could derive the answers to these questions.In CoKoMo, we have struggled some to find the right ontology - or "knowledge model". Our central findings are this: the formulation of the meta-model for the ontology of education can only come from the use cases of the stakeholders. So, it doesn't make sense to ask computer science about possible formulations of ontologies and then choose one.

The problem: the requirements of stakeholders, especially of future ones, are not known.

Curricula, Learning Objects, Search Engines – All Relate to Knowledge!

To better understand the stakeholders in the education system, we have meticulously listed all the people and functions that appear important to us for educational production. We started with teachers and students, parents, developers of learning objects, and curriculum designers. We have broken down traditional learning management systems into providers for a catalog of learning objects, learning tests, learning analytics, quality management, etc. In addition, there are functions that are not explicitly described in traditional education - such as the educational concept developer - or functions that do not exist yet - such as decision systems for the delivery of pedagogical interventions.

Examples of algorithms that should be provided by "our" stakeholders include:

an analysis module that models the status of an individual based on inputs from learners - such as test results or statements;

a decision module for pedagogical interventions that makes individual and situationally motivated decisions about the next teaching intervention;

an "experience" module of formalized intervention tracks that are considered meaningful from a didactic perspective; here, AI could also have its first application;

a catalog module with learning objects
(texts, videos, tests, project tasks, etc.).

In our conception, all these and other stakeholders relate to a domain of knowledge as a key production factor. We use the term "learning objective" as the most detailed formulation of a knowledge element. Three examples:

- A curriculum defines a segment of world knowledge as an aggregation of learning objectives for a (certifiable) qualification.
- A teaching intervention aims to achieve a learning objective as efficiently as possible.
- A learning object conveys knowledge elements related to a specific learning objective.

The clearer a domain of knowledge and its elements can be addressed, the better stakeholders - both humans and computers - can orient themselves in a collectively agreed-upon knowledge space and benefit from it in educational production.

Requirements for Knowledge-Models - Yesterday, Today, and Tomorrow

Our first and most important task in CoKoMo was to define a specific meta-model for capturing knowledge to implement it in a web application. This meta-model determines the categories of elements that make up the knowledge in our model and the rules for creating them. For pragmatic reasons, we focused entirely on conceptualized/abstract knowledge.

The requirements of the diverse stakeholders, which we can derive from our value network, differ significantly. Therefore, we have chosen a representative who represents the most demanding requirements of future services: the "Intelligent Tutoring System" (ITS).

It stands for an algorithm-based agent that individually supports a student in learning. An ITS is thus the "digital twin" of a human teacher. With the ITS as a reference, we can illustrate how humans and machines can use the model in a comparable way.

The inherent challenge of the agent is to formulate an appropriate, subject-specific teaching intervention based on perceptions of a learning individual.

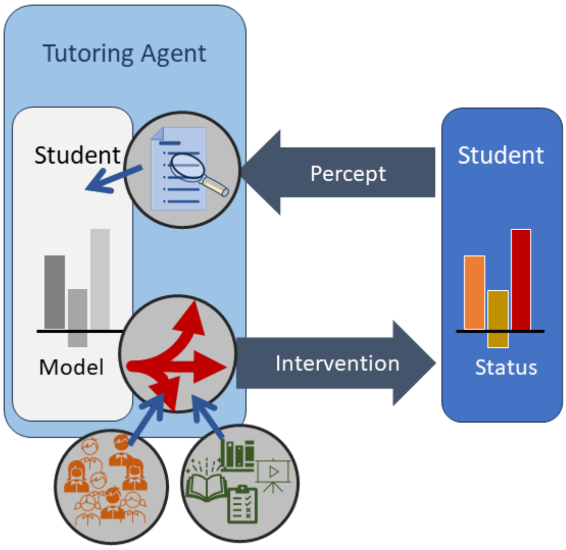


Figure 2: Functions of a Tutoring Agent.

For this, "analysis" and "decision-making" functions are required. Decisions in terms of purposeful pursuit of a goal (teaching intention) require action options, i.e., "experiences." And finally, a concrete learning intervention must be delivered, which the agent retrieves, for example, from a pool of learning objects.

So, we are asking about possible formalizations of pedagogical actions. And we found them among cognitive scientists and educators from the USA in the 1980s. It is noticeable that the protagonists of these models were often physicists or engineers, who gave these formalizations a common imprint.

The beginning, however, is made by the psychologist Benjamin Bloom with his learning objective taxonomy, which has been adapted in many contexts - up to the qualification framework for German university degrees. We have borrowed further structural elements for knowledge representation from the works of cognitive scientists, especially Frederick Reif, Andrea diSessa, and Alexander Romiszowski.

Based on their work, our rough concept for the functions of a tutoring agent was developed, as a test-bed for our model. The real purpose behind this is the design of an effective knowledge model. It is important to note that the functions of the agent must always refer to the same knowledge model to function as outlined. With the shared knowledge model, another important aspect of data protection comes into play: the agent can operate autonomously in the data space of, for example, a student - the functions of the agent do not require an exchange of personal data with external systems. We assume that data economy provided for by our knowledge model will be a crucial competitive advantage in the German education system.

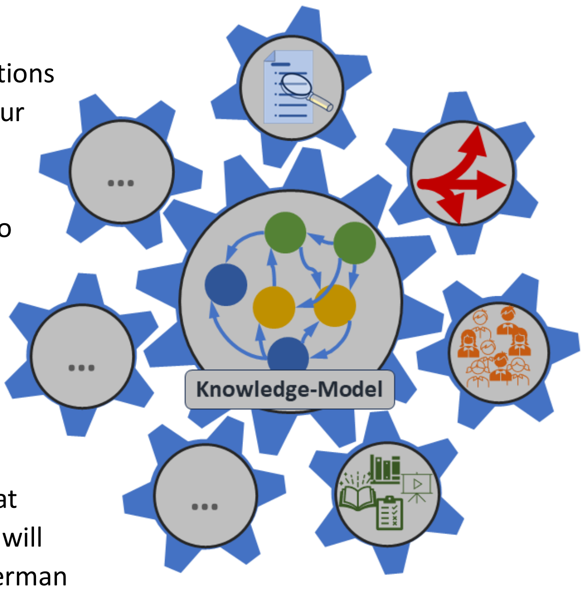


Figure 3: The normative knowledge model as an integration node for EduTech applications

We Introduce: CoKoMo

The result of our development is a meta-model for conceptualized knowledge. The accompanying web application "CoKoMo" is freely available at:

- https://cokomo.code4you.com

The interfaces to our data model for humans (the GUI) and for machines (API) are documented on the pages:

- https://CoKoMo-IT.de

Upon registration, we also provide a demo model for mathematics knowledge from the curriculum of secondary school level.

In our model, we distinguish between two manifestations of knowledge:

- Structuring knowledge by terms with their semantic relationships.
- Capturing the depth of learning, which we call competence..

Terms and Meaningful Contexts

As an example of a knowledge model, we present here the solution scheme "Statics of Rigid Bodies" from the field of Engineering Mechanics for the first semester of a Bachelor program at the University of Applied Sciences Hamburg:

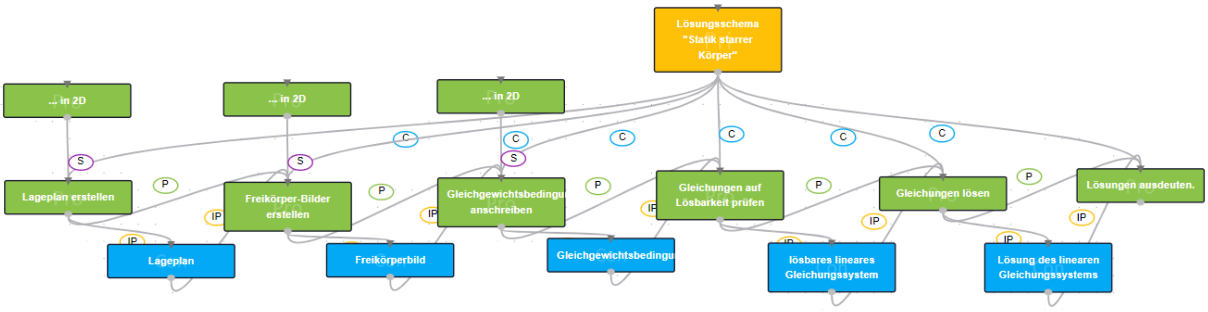
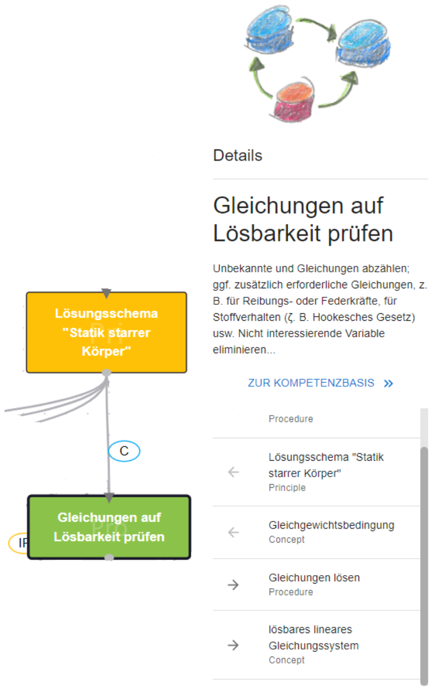


Figure 4: Excerpt of the knowledge model for the module "Engineering Mechanics".

The figure displays cards in different colors. These represent terms in three different categories. For example, the blue card "Free Body Diagram" stands for the conceptualization of a free body diagram. A green card, such as "Write equilibrium equations," represents a process in which the (equations of) "equilibrium conditions" of the system are derived from a free body diagram. And the yellow card represents the principle of the "solution scheme 'Statics of Rigid Bodies' ". So, the three categories for knowledge elements in our model are "Concept" (conceptualization), "Process," and "Principle."

The instances of these three types of knowledge elements are linked together through semantic relationships or inferences. For example, the "Free Body Diagram" is the result ("product of") of the process "Create free body diagram." We have also defined permissible categories for these semantic relationships.

Each term comes with its type and its connections to neighboring elements displayed. Under the menu item "Competency Base," there is a description of the knowledge element and further information – such as a collection of alternative terms for an element. For the process “Create free body diagram”, an alternative term is “Separate Bodies”. If one searches in the model for the knowledge element “Separate Bodies”, they will end up at the element with the official name “Create free body diagram”.



Figures 5: Details for the element "Check equations for solvability".

Competence: The Depth-Dimension

Each of the knowledge elements in CoKoMo is underpinned by Bloom's taxonomy with its learning objectives. This means that for each element, there is a series of learning objectives at each of the six competency levels. For example: “I explain the relevance of checking the system of equations for the static equilibrium of a system for solvability”. According to Bloom, this statement belongs to the second category "Understanding" of Bloom's taxonomy of learning objectives.

Is CoKoMo the „Right“ Knowledge-Model?

By qualitatively subdividing a knowledge domain into terms (elements) with their respective semantic relationships, we project its semantics into a graph model. The competency dimension further enables us to systematically capture competence for each element.

This approach combines established and proven formalizations of knowledge as described by learning psychologists, cognitive scientists, and educators. It is by no means the only possible formalization of knowledge. Just as there are various ways to design screws, there are also various ways to design meta-models for knowledge. The economic and organizational value lies in the normative character of the model: the goal is to establish a common understanding among involved individuals and organizations in a market. This enables production factors to be exchanged smoothly and efficiently between market participants.

Conclusion

Traditionally, German education is understood as a self-service market compared to other, especially Nordic, countries: government authorities prescribe a curriculum, teachers present its contents, and students either take advantage of the offerings or not. It is similar at universities. But this German model of a “conservative educational state” has apparently reached the limits of its viability – as it no longer meets the requirements of a heterogenous society. And now what?

A new, more effective and cost efficient form of education will have to offer more services for students, such as coaching, individual tutoring, and appropriate support for independent learning. For this paradigm shift to work for teachers and learners, innovative IT solutions are needed to support the new educational production with novel market-economic approaches.

Here we see CoKoMo as an enabler for new technologies in a distributed and open, future EduTech market. As a normative interface for people and teachers, our knowledge model provides the basis for an exchange of interests between individual persons, public institutions, and market-economically operating companies – a market in which consumption- or investment-oriented perspectives on education and upbringing alone fall short.

Our Conclusions:

- The impending paradigm shift in educational production, similar to the industrial revolution, needs normative interfaces between stakeholders as "enablers" for the entry of SMEs into the future market. This is intended to open up state-bureaucratic educational production in a measured way for services from companies.
- CoKoMo can be a potent instrument of the institutionalized regulatory system. In the upcoming discussion about economization or privatization, it can help bring the desired actors with their investments and innovations into the education market.
- The decisions about the right form of these regulatory systems are ultimately political, not technical.

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Links to CoKoMo

- https://cokomo.code4you.com
- https://CoKoMo-IT.de

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