Chapter 4
Twenty-First Century Skills Education in Switzerland: An Example of Project-Based Learning Using Wiki in Science Education

Chapter 3 has introduced teaching pedagogies and learning strategies that promote and sustain the development of twenty-first century skills among students in the fields of the social sciences, humanities, and languages. It has also illustrated approaches used in collaborative teaching, inquiry-based learning (IBL), project-based learning (PjBL) as well as the use of social media tools such as wiki that are potentially conducive to student learning (e.g., Chu 2008; Notari 2006; Tavares et al. 2011; Woo et al. 2011). These methods and tools not only encourage exchange of ideas, comments, and constructive feedback (Mak and Coniam 2008) but also foster collaboration (Notari 2006), improve work quality (Chu 2008) and cultivate social skills in the course of negotiation (Fung et al. 2011; Notari et al. 2014). When learners are challenged to rethink and restructure their ideas, it helps to develop their skills and cognitive abilities that go beyond those of the actual subject matter.

Compared to instruction in the social sciences, humanities, and languages, a slightly different approach is required to promote twenty-first century skills in science education. The goal of science education is to develop students' scientific literacy, involving the understanding of scientific norms and concepts, and the ability to reproduce scientific content and express the related matters autonomously and adequately (Miller 1983). In order to achieve this goal, approaches in addition to those outlined in Chap. 3 are needed. As such, this chapter first presents an overview of the various approaches that could be used to scaffold learners' development of scientific literacy, followed by an introduction to the methodological approach ABAHCOCOSUCOL (Notari 2006) which was initiated in Switzerland to improve science instruction in high schools. Guided by the progressive inquiry-based model proposed by Hakkarainen and Sintonen (2002) and Muukkonen et al. (2008), ABAHCOCOSUCOL makes use of a technology-supported environment to create room for interactivity and participation. Students produce a wiki out of questions and explanations embedded in a hyperlink structure, in which they review, restructure, rewrite, and reorganize their collaboratively produced contents. This structure of production, comparison, and regrouping results

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in a sharing of expertise among learners and promotes knowledge acquisition, transfer, and consolidation. The combination of the most relevant aspects that support scientific literacy and their embedment into an interactive learning environment facilitates the development of critical thinking skills, active participation, cognitive abilities, and twenty-first century skills.

4.1 Notable Aspects of Science Education

Many approaches and models have emerged to describe and analyze science education and proposed important aspects that might be helpful for its advancement. Their goal is to conceptualize instructional design and the development of skills and competences that improve learners' achievement.

4.1.1 Models of Science Education

The competence model HarmoS ("Harmonisierung der obligatorischen Schule") appeared in the course of an educational policy reform in Switzerland to describe the development of skills and competences that learners are expected to demonstrate in science subjects (Labudde and Adamina 2008; Ramseier et al. 2011). This model was designed by a consortium for science education in Switzerland to determine the goals of science education and to create a corresponding competence model to validate, revise, and suggest basic standards illustrated by concrete examples (Ramseier et al. 2011) (Fig. 4.1).

The model is constructed as a three dimensional matrix that spans the instructional framework of science education. The first dimension, representing skills, lies on the horizontal axis. The second dimension positioned on the intersecting vertical axis captures the domains of the concerned subject, and the third dimension on the vertical axis shows the varying levels of difficulty (Ramseier et al. 2011).

The consortium for science education in Switzerland places the behavioral aspects on the primary axis, with the vertical axis orienting around the primary axis. Every behavioral aspect can be measured by four difficulty levels defined on the vertical axis to be reached at the end of grade 2, 6, and 9, respectively. The difficulty heightens from "simple exploration by doing" to "exploration by asking and doing" and from "research oriented explorations" to "organization and realization of research oriented explorations" (Labudde and Adamina 2008). Consequently, the matrix signifies a broad and complex framework of level descriptions which was designed according to progression logic. A horizontal progression would imply that an increasing number of aspects are to be included; the additional dimension that holds the teaching content on the horizontal axis is further divided into eight sub-aspects that represent specific subcategories of the teaching content. On the vertical axis, progression along the axis reveals a higher

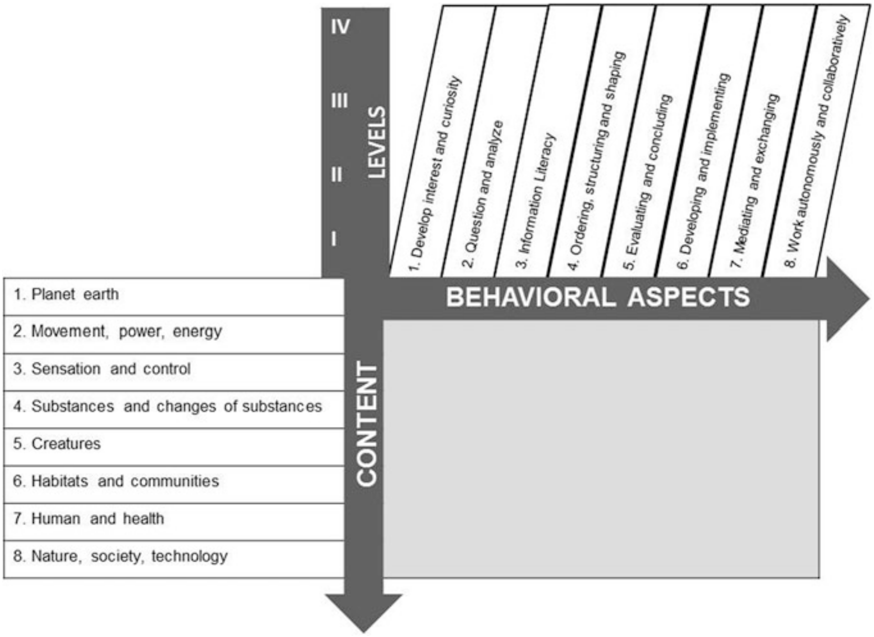

Fig. 4.1 The HarmoS competence model (adapted from Labudde and Adamina 2008, p. 354)

differentiation among the partial aspects and an increased requirement of competences (Ramseier et al. 2011).

The effort of the consortium to shape and define competences for science education is a trend in many different countries all over the world. This raises the question as to whether these models have to be designed country-specifically or if they actually share certain underlying competences (Labudde and Adamina 2008). According to Labudde and Adamina (2008), the models all originate from the concept of scientific literacy, a term that has been prevalent in the discourse of science didactics for many years. However, scientific literacy is a term that is “often used, but seldom defined” (Miller 1983, p. 29). Generally, it can be regarded as a combination of understanding scientific norms and knowledge of major constructs in addition to the ability to reproduce scientific content and express the related matters autonomously and adequately (Miller 1983). Based on the Programme for International Student Assessment (PISA), a scientific literate person is expected to possess the following knowledge and abilities (Hammann 2006):

- Understand basic scientific concepts
- Understand science and the application of scientific knowledge
- Possess scientific knowledge and be able to distinguish it from nonscientific knowledge
- Have the ability and motivation for autonomous life-long learning
- Have the ability to use scientific knowledge to solve problems

- Possess knowledge to participate in scientifically motivated social discussions
- Understand the Nature of Science (NOS)
- Meet science with appreciation, curiosity, and astonishment
- Possess knowledge about usage and risk of science
- Critically reflect on science and be able to handle scientific expertise.

The points listed above suggest that it is crucial for students to understand and apply scientific concepts. Therefore, concept learning is a salient aspect of the instructional design of science education (Labudde et al. 1988). "If students have a fragmented knowledge base, inadequate retrieval processes and the inability of distinguishing between concepts and reasoning modes used in science as opposed to those used in everyday life" (Labudde et al. 1988, p. 81), they can only attain a superficial understanding of scientific concepts. These problems often arise because of the form of mediation of a new scientific concept, especially in the area of Physics and Mathematics, where teachers tend to explain a new concept by introducing the verbal or mathematical definitions that describe the significant features of a concept. However, little is conveyed about the actual process that governs identification or construction of a concept and students have to deduce this procedural knowledge on their own, which is often complicated by insufficient interpretative abilities. To go further, the mediation of concepts often lacks explicit references to existing conceptions. Scientific concepts ought to be set in a comparative context to enhance cognitive linking between new and preexisting knowledge and establish integration and accommodation, both required for effective learning (Labudde et al. 1988; Piaget 1970). These difficulties lend themselves to the suggestion of instructional principles for more effective teaching of scientific concepts. Procedural knowledge for interpreting scientific knowledge has to be taught in combination with the corresponding definition and description of a concept. New knowledge has to be mediated coherently to guarantee memorability and contextualization within the conceptual framework that already exists with a focus on facilitating the integration of new content into preexisting frameworks. This approach of embedding and contrasting acquired knowledge within and with the prior conceptual framework supports the elimination of inconsistencies and establishes a coherent knowledge base (Labudde et al. 1988).

A method that presents a promising solution in this respect can be found in constructivist learning (Widodo and Duit 2004), generally defined as the act of active construction of new knowledge or skills out of preexisting capabilities of teachers and students (Labudde 2008). A constructivist learning environment can be beneficial in many different ways. A study on the general characteristics of such methods reveals that a learning environment that enhances curiosity and inquiry, creative and revolutionary thinking, collaborative and autonomous learning and integration of scientific concepts is the key to constructivist learning (Widodo and Duit 2004). In line with this, Labudde (2003) points out that a constructivist learning approach would most often lead to interdisciplinary science instruction, an approach that supports students' understanding of scientific concepts, as they are mediated in a broader context. Interdisciplinary teaching takes the advantage of the interrelation of the scientific subjects like Biology, Chemistry, or Physics. By combining these scientific subjects, the science curriculum can be more comprehensive. A model was developed by Labudde et al. (2005) to ensure effective and successful interdisciplinary teaching in science education while describing and defining its multidimensional complexity (Fig. 4.2).

Derived from the current body of research on interdisciplinary teaching and targeted surveys, the model contains seven dimensions that cover several parts of the approach. Every dimension is further divided into three to four facets, each representing one branch of a mind-map that spans the whole multidimensional space of the model. The facets themselves consist of several components that are distributed over a defined range close to the branch itself, either closely related to a specific subject or rather interdisciplinary aligned. Special attention should be directed to the dimension "Transferable Skills" that resembles the twenty-first century skills outlined. Labudde et al. (2005) emphasize the significance of aspects like "Information Literacy," "Ability to cooperate," "Ability to differentiate and integrate," "Tolerance of Ambiguity," or "Problem-solving skills" and the shift the focus to skills and competencies beyond the actual subject matter.

In relation to this approach, a theoretical framework (Fig. 4.3) is developed to safeguard the quality of instruction in Physics education (Fischer et al. 2014). The model concentrates on four dimensions: Teacher, Instruction, Student, and Outcomes, and contains a number of variables that have been found to have a positive impact on students' achievement in science instruction based on previous research.

In the above model, teacher-related factors, including teachers' professional knowledge, enthusiasm, and their background in terms of teaching experience, and

Fig. 4.2 The multidimensional model of interdisciplinary teaching (adapted from Labudde et al. 2005, p. 105)

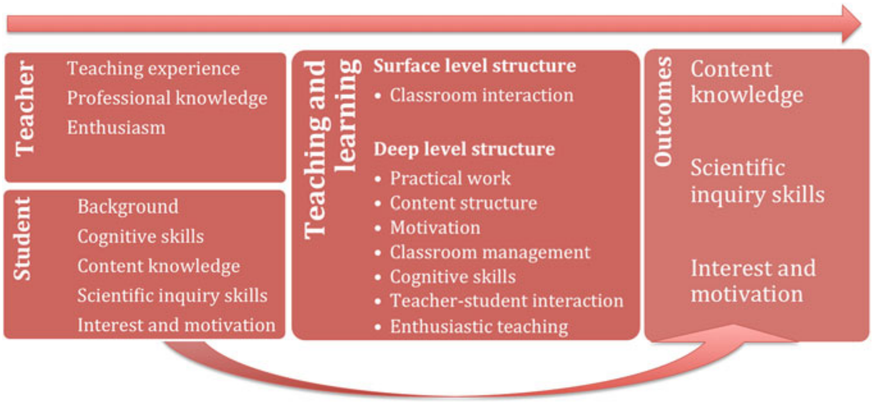

Fig. 4.3 Model of quality instruction in physics (adapted from Fischer et al. 2014)

student-related factors, such as their cognitive ability, prior knowledge, inquiry skills, interest, and motivation and general background, are factors that positively influence the quality of instruction (Fischer et al. 2014). The dimension "instruction" is divided into two levels—surface and deep. The surface level contains directly observable characteristics like the form of classroom interaction. The deep level focuses on cognitive activation, structure of the content, management of the classroom, motivational support and learning orientation, practical work, as well as teacher–student interactions and the teacher's behavior. The "Outcomes" are primarily concerned with the concept of scientific literacy with respect to the students' content knowledge and their skills in the area of scientific experiments. In addition, Fischer et al. (2014) introduced the aspects of motivation and interest as an instructional outcome. As Fig. 4.3 suggests, teacher-related variables affect instruction and therefore implicitly impact on the instructional outcomes, whereas student-related factors have a direct effect on this variable. Even though the model was originally constructed to investigate instructional differences in Physics instruction among Germany, Switzerland, and Finland teachers, the instructional factors illustrated in the model are highly relevant to the learning success of students and the constructional principles can be applied to enhance science education and support scientific literacy in different contexts.

With regard to the intentions of creating this proposed model, IBL and PjBL offer a promising solution to meet the qualitative requirements of scientific instruction. Referring to the "Instruction" dimension of the model, inquiry-based learning presents students as active agents in a constructivist information search process that covers Initiation, Selection, Exploration, Formulation, Collection, Presentation, and Assessment (Kuhlthau 2004; Kuhlthau et al. 2007). Kuhlthau (2010) recommends that in a constructivist guided inquiry-type learning environment, the instructional team holds an observational perspective to teach and assess learners and be sensitive to learning needs that emerge. In contrast, a progressive inquiry model (Hakkarainen and Sintonen 2002; Muukkonen et al. 2008) sees the teacher as the creator of a context for inquiry by introducing a multidisciplinary approach to a theoretical or real-life phenomenon, after which the learners start formulating their own questions. The questions and explanations are shared and evaluated together, which involves utilization of authoritative information sources and iterative elaboration of subordinate study questions and more advanced theories, explanations and writings. The progressive inquiry model is not meant to be adhered to in a rigid manner; rather it offers conceptual tools to describe, understand, and take into account the critical elements in collaborative knowledge-advancing inquiry (Hakkarainen and Sintonen 2002; Muukkonen et al. 2008). The approach of project-based learning allows students to explore their own interests, thus nurturing their individual strengths and enthusiasm in project work (Blumenfeld et al. 1991; David 2008; Marx et al. 1997; Thomas 2000). This is found to be effective in stimulating learners to actively engage in information search and data evaluation (Prince and Felder 2006). The possibility to combine it with a form of inquiry learning is a promising learning strategy (Chu 2009; Krajcik et al. 1998) to achieve the positive instructional outcomes proposed by the model. This form of integration, called inquiry PjBL, combines constructivist principles with the idea of providing support to individuals through working on and extending their development.

4.1.2 Supporting Science Education with the Use of Technology

In the area of science education, IBL and PjBL have been shown to support cognitive abilities like critical thinking and reasoning, and the acquisition scientific knowledge (Olson and Loucks-Horsley 2000). Students are actively engaged in a learning process shaped by inquiry, which resembles scientific inquiry and implicitly mediates scientific skills (Anderson 2002). However, for the successful deployment of a learning environment, it is vital to include the use of various tools and learning structures that enhance and facilitate students' adaptation to it. Hmelo-Silver et al. (2007), for instance, place emphasis on scaffolding with respect to task structuring and the externalization of disciplinary thinking and strategies. Edelson (2001) illustrated the advantages of the use of technology in science education. He introduces a technology-supported inquiry learning approach and depicted the learning cycle that involves motivation, knowledge construction, and knowledge refinement. This incremental construction process can be regarded as a way of translating the inquiry process used by scientists to advance human understanding into a process that can be adopted by teachers and students to "strengthen students' understanding" (Edelson 2001, p. 360).

There are several ways in which technology enhances scientific inquiry learning. First, experiments and practical work can be done in virtual laboratories. A literature review of 135 empirical studies in the ERIC (Education Resources Information Centre) database and PsychInfo shows that visualization of experiments helps students overcome conceptual errors by making explicit the links between information and facts (Wu and Shah 2004). It was found in Greece that students had better academic performance and a more positive attitude toward Physics courses that integrated the use of digital simulation tools in laboratory work (Baltzis and Koukias 2009). A study conducted in Cyprus also revealed that the use of simulations together with real experimentation strengthened students' understanding of scientific concepts, when compared to the approach of using real experimentation alone (Zacharia 2007). Students carried out experiments, either guided by a teacher (Donnelly et al. 2013) or in a self-directed manner (Kluge 2014; Liu 2006). In the study done by Donnelly et al. (2013), Irish secondary school students were given the freedom to design their own experiments under the teacher's guidance. Teachers reported that students were able to carry out the experiments at their own pace, and were all making an effort to solve the problem at hand by trying out different approaches. In Kluge's study (2014), upper secondary students in Norway completed a Biology group project with the assistance of a digital laboratory. They were required to design the experiment using the digital platform, discuss the results, and present them to their peers. Analysis of students' performance suggested that engaging them in post-experimental work is instrumental in helping them associate the results of experiments with the relevant scientific theories.

The aforementioned simulations have often been reported to be applied in class. Apart from classroom use, students may benefit from technology use outside the classroom. For example, a collaborative learning environment named "smart classroom" has been codesigned by scholars and Physics teachers to hone students' collaborative problem-solving skills in Canada (Tissenbaum et al. 2012). The collaborative learning environment made use of Web 2.0 technology, enabling teacher–student and student–student interaction both in and outside the classroom through a series of in-class exercises, homework, and take-home group tasks. Before class began, the platform generated aggregate reports on students' performance to support teachers' lesson planning. During class, student responses to questions were compiled and shown on a large projected display. This facilitated teachers' understanding of student knowledge and allowed them to give specific feedback. Group take-home assignments done on the platform were also observed to help develop students' collaboration skills. The study results indicated that access to peer work was a great resource and effective in students' sense-making. Teachers in the United States were also noted to benefit from the student-generated content, as they were able to see patterns in student responses in order to engage them in more in-depth class discussions and to clear misconceptions (Hake 1998).

4.1.3 European Policy Concerning Twenty-First Century Skills

After introducing different models of science education and ways in which technology can support science education, this section examines the significance of acquiring twenty-first century skills in the European context. The European e-Competence Framework 3.0, a part of the European Committee for Standardization, has created a reference of 40 competences as required and applied it at the Information and Communication Technology (ICT) workplace, using a common language for competences, skills, and capability levels that can be understood across Europe (CEN 2013). The framework enables the identification of skills and competences that may be required to successfully perform duties and fulfill responsibilities related to ICT in both the private and public sectors.

"Structured in four dimensions, the European e-Competence Framework reflects different levels of business and human resources (HR) planning requirements, including job proficiency guidelines" (CEN 2013).

- Dimension 1 embodies five e-competence areas, derived from ICT business processes: Plan, Build, Run, Enable, and Manage.
- Dimension 2 defines a set of e-competences for each area, with reference to definitions for 40 different competences in total.
- Dimension 3 sets out proficiency levels (e-1 to e-5) of each e-competence, which correspond with levels 3–8 in the European Qualification Framework (EQF).
- Dimension 4 provides examples of knowledge and skills that relate to the specific e-competences defined in dimension 2 (CEN 2013).

Within the 40 e-competencies identified in Dimension 2, several competencies fit the general understanding of twenty-first century skills, for instance, innovating, testing, problem management, personnel development, information, and knowledge management, as well as project and portfolio management.

In the communication from the commission to the council of the European parliament, the European economic and social committee and the committee of the regions, the following policies regarding twenty-first century skills were formulated to foster competitiveness and growth in both the public and private sectors (CEN 2013).

– **Longer term cooperation**: solidifying cooperation between public authorities and the private sector, academia, unions, and associations through the advocacy of multistakeholder partnerships and joint initiatives including monitoring supply and demand, anticipating change, adapting curricula, attracting foreign students, and highly skilled ICT workers and promoting ICT education on a long-term basis.
– **Human resources investment**: ensuring sufficient public and private investment in human resources and e-skills, and appropriate financial support and fiscal incentives, in full respect of State aid rules, as well as developing an e-competence framework and tools facilitating mobility, transparency of qualifications, and promoting recognition and credit transfer between formal and nonformal and industry ICT education and certifications.

The following section will provide an example of an inquiry-based learning project using a participative technology named ABAHCOCOSUCOL, an action and participation method based on collaboration among learners (Notari 2006). This project-based learning approach for higher secondary education addresses the skill sets proposed by the European Community, focusing on problem management, personnel development, information and knowledge management, and project and portfolio management.

4.2 An Example of a Project-Based Inquiry Learning Approach in Switzerland Using Wiki as a Co-authoring and Collaboration Tool

4.2.1 Implementation Model

The implementation of the scenario follows the ABAHCOCOSUCOL (Action BAsed, Hypertext—COnstructive, COmputer SUpported, COllaborative Learning) method of collaboration using wikis (Notari 2006). It was developed in order to help teachers design an appropriate inquiry-based collaborative learning environment and scaffold students' activities during the active learning phases. ABAHCOCOSUCOL is based on the progressive inquiry model proposed by Hakkarainen and Sintonen (2002) and Muukkonen et al. (2008). This methodological approach is designed for use in formal learning settings with high school students as the target audience. The method has not been used in environments with students of an education level lower than grade 8 (Notari 2003).

Scripting for ABAHCOCOSUCOL consists of four phases: (1) Creating content using a hypertext, (2) Linking concepts, (3) Comparing and peer-commenting, and (4) Regrouping concepts within the hypertext. The initiation phase leads students into the problem and gives them an indication for an appropriate first action. In this phase, there is no big difference between ABAHCOCOSUCOL and "conventional" teaching. Learners receive an introduction to the subject by the teacher and start creating the hypertext-content either individually or in small groups. It is crucial that enough content (called 'critical mass of input') is created in the first learning phase. The comparison phase should start immediately after the critical mass of input has been established. Within the comparison phase, learners are invited to read the work of their peers and then to find and link similarities within the created content. The learners can compare immediately and simultaneously the content created by their peers. Such a comparison of ongoing work within a learning community is difficult to realize in a traditional (noncomputer supported) curriculum. Being aware of all other forms of inputs of the community, an individual learner can compare the quality of his/her contribution with that of other contributions, get a formative evaluation of his/her work, and enhance social competences and metacognitive skills through commenting on others' tasks. The feedback and comment culture described above leads to a regrouping of the content. Students then proceed to the regrouping of the work produced, which aids in the construction of mental models of the different concepts and is fruitful for learning. This sets the stage for the discussion phase. It needs to be stressed that these phases can be repeated more than once. At the end of the learning unit, a discussion should give students the opportunity to formulate and discuss different opinions or concepts. The positive feedback cycle of production, comparison, and regrouping can also be formulated as shown in Fig. 4.4.

The term scripting describes teachers' activities with students and with the wiki. Scripting should facilitate students' publication of what they have produced as soon as possible, with an "evolution" of the content within the unit as a response to the comments and questions of the other members of the community. Although further input can be created during the learning unit, for instance, when new questions arise, the "critical mass" of input at the beginning is essential to initiate interactions among students and the creation of a communication culture. The linking of concepts is salient for raising students' awareness of the common goal and the cross-linkage of the concepts of the unit covered. The learning community co-constructs one collaboratively elaborated hypertext where the different pages are interwoven and linked. Creating links sustains the awareness of the community and gives a basis for the comments and comparisons produced as further actions of the students. Finally, the distillation and regrouping of relevant information lends itself to self-evaluation of the product of the learning community.

The principal settings of ABAHCOCOSUCOL can be used for a wide range of educational purposes. They are not bound to a specific school subject or to a learning environment where students and the teacher see one another regularly. The major advantages of the model include the quick setup when the model is applied using a wiki, the considerable adaptability and the scalability of the system. ABAHCOCOSUCOL has been adopted with high school students in different nonexperimental learning settings and in a blended distance education course about media methodology with adults. Applications of ABAHCOCOSUCOL have shown good learning performances concerning the following competences and skills:

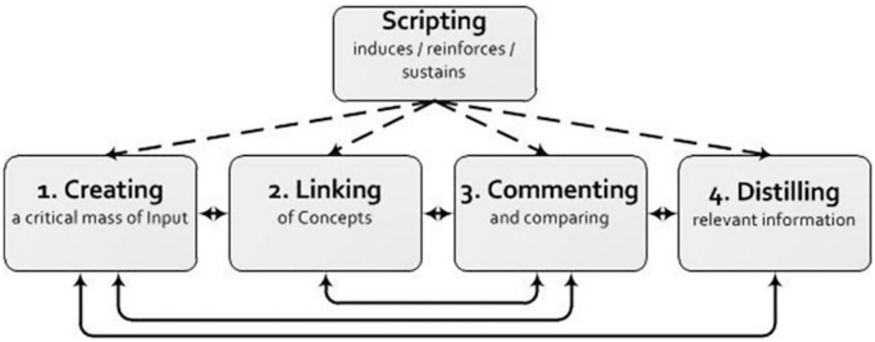

Fig. 4.4 ABAHCOCOSUCOl method (reproduced from Notari 2006)

increase of factual knowledge, long-term knowledge retention and metacognitive skills, development of problem-solving strategies, ability to construct a hypertext, link concepts, and distil relevant information to regroup concepts (Notari 2003).

4.3 Case Study: Creating a Collaborative Glossary in Science Education: "Evolution"

Entrusting learners with the task of creating or cocreating a glossary of the learning topic helps them better remember core elements and concepts and enhance their vocabulary, writing skills, and semantic skills (Schneider et al. 2004, p. 28). Schneider describes six steps for making the glossary:

1. "The teacher and students identify and determine the terms to be defined related to a theme they do not master.
2. The alphabetical list of terms to be defined is entered in the interactive space chosen.
3. Students search the web or in dictionaries resources on the theme.
4. Students synthesize their results to create short definitions.
5. The teacher checks if the definitions are right.
6. Students enter their definitions".

Collaborative glossaries can be compiled using different technological tools. Moodle (a learning management system) offers a specific module (glossary Module, see https://docs.moodle.org/26/en/Glossary_module) where learners of the same course can access the same page and have equal rights to edit and change content of the page. Notari and Doebeli (2012) chose a Wiki to set up a collaborative glossary scenario for biology education at high school level. The created collaborative glossary was used for a learning community of two classes working simultaneously on the same topic with the same teacher. The collaborative glossary was part of a learning unit which was an introduction to evolutionary biology. The primary goal of the evolution unit was for students to get an overview and understand different abstract concepts. Evolution is part of the Biology curriculum of 11th grade high school students in Switzerland. Students at that age already have fundamental knowledge of genetics, taxonomy, and the development of species but the concept of a scientific theory has never been previously mentioned. The abstract definition of the theory—the validity of hypotheses—is retained until one of the hypotheses is proven to be false. It is difficult to separate the term "theory" from belief. As students have learned the basic concept of the possible origin of living organisms and the way genetic information is passed on from one generation to the next, they can imagine how genetic information itself, and through it, life can survive through time. This way of looking at the possibility of survival of genetic information from an organism through time could lead to a hypothesis about evolution of organisms.

4.3.1 Time Schedule, Group Building

The unit spanned across four lessons (180 min) for each class. Before the start of the unit, about one-and-a-half lessons were spent introducing the tool. The students had two periods of lesson time to complete learning tasks assigned to them.

4.3.2 Specific Goal

The chief aim of the learning unit was to create a collaborative glossary with the definitions of the pertinent terms related to evolution, to link all the similar concepts and to re-group different terms under specific categories.

4.3.3 The Collaborative Glossary

As illustrated in Fig. 4.5, after a short description of the unit, the different goals and the wiki, the participants were instructed to search for terms concerning evolution. Then they had to write a comprehensive definition of the term and publish it on the wiki. A second task was to search through the definitions written by the other students and find similar terms. These terms then had to be linked to their own definition. A third task was to group similar definitions, e.g., names of researchers such as Darwin, Lamarck, Cuvier, etc. After the first contact with the tool, students began to formulate definitions and create new pages. The project team tried to correct mistakes in the definitions. They read the texts written by the students, gave feedback and assisted them with the literature search and research on the Web. Students were advised to cite all the input and to make references to the literature or the Website where they found the information and were reminded to keep their definitions short and concise.

The project team encouraged students to give their own definitions for the terms, as the goal of creating the dictionary was to construct definitions adapted to their state of knowledge. Many definitions found on the Web were too complicated and full of unfamiliar words. At the beginning, students merely copied the definitions they managed to find. After a while they showed more and more attempts to adapt the definitions they found or at least to explain all the foreign words and difficult sentences. After the first two lessons, the project team reinforced the linking of concepts. Students were presented with the task of searching for similar words and definitions and trying to link them to other concepts. They were also told to complete definitions or to add definitions of terms whenever necessary as they read the texts. The team created opportunities for the students to group similar terms on the starting page and build new categories of terms, for instance, by putting all the names of researchers under a category.

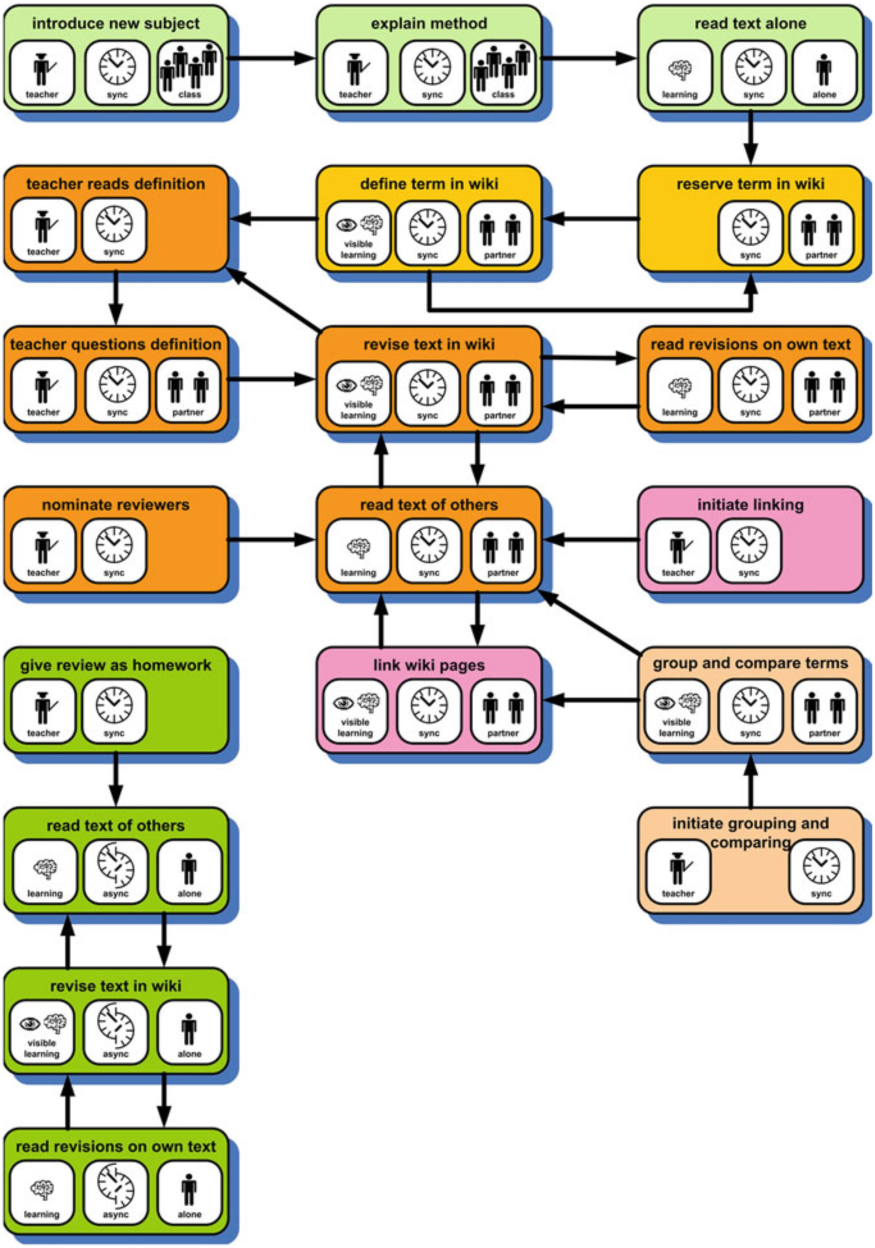

Fig. 4.5 Collaborative glossary "evolution" (reproduced from Notari and Doebeli 2012)

The mass of collaborative hypertext grew exponentially. At the beginning of the course, students mainly copied definitions of scientific terms from the Internet randomly without truly understanding what they had posted. Students were asked to read other definitions as homework, and to pose questions if they did not understand terms or sentences. At the start of the second lesson, it was announced to the students that all definitions had to be learned for the final assessment. Given this input, the contents of the definitions changed dramatically and the amount of questions of the readers increased and became more precise and pertinent.

Three different formative evaluation elements were implemented within the curriculum. The wiki allowed students to see the work in progress of all learning groups. They were advised to periodically read and comment on the contributions of other members in the community. At the initial stage, they reported feeling uncomfortable making comments on the produced artifacts of other groups. Similar results were recorded in comparable studies in Asia where sociopsychological factors such as conformity were observed where students expressed contradictory views (Venkatesan et al. 2014). As students progressed further in the project, the comments became more and more structured and also diversified. In the second phase, the project team urged them to link similar concepts of the created artifacts. The teaching team wanted them to find conceptual similarities and raise their awareness of connections between the created definitions within the glossary. In the subsequent formative evaluation, students were instructed to group and re-group definitions in order to build new categories of terms. This intervention was introduced in order to enhance students' higher order thinking skills. Peer-evaluations were involved but teachers also gave feedback on students' work and suggested possible links between related content and assisted with the regrouping of concepts in the glossary.

On the whole, the project-based curriculum was found to be beneficial in enhancing students' inquiry capacities. Through working on the project and managing their portfolios, students sharpened their information research skills, especially in retrieving relevant content from the identified digital artifacts. They also showed gains in their problem management, information and knowledge management skills.

4.4 Conclusion

This chapter provides a literature review on concepts and models of science education in Europe and documents a case study that illustrates the advantages of technology-enhanced collaborative Biology learning and its impact on facilitating the development of twenty-first century skills among secondary students in Switzerland. The findings of the case studies support the use of technology-enhanced inquiry-based science learning as a promising teaching and learning approach. Such an approach is expected to be most effective when social media technologies are utilized in an appropriate way and teachers use adaptive strategies to scaffold student collaboration and guide them in fruitful knowledge creation. Applying the inquiry-based model proposed by Hakkarainen and Sintonen (2002) and Muukkonen et al. (2008), as well as the ABAHCOCOSUCOL method advocated by Notari (2006), we cited examples of how science can be taught to twenty-first century learners and how wiki-based technology can raise students' competences in the subject matter and aid formative evaluation of student work and progress.

Science education offers different opportunities for teachers to incorporate technology into the learning process. Technology can be used for measuring parameters like temperature, weight, and electrical power or with more powerful tools with multiple sensors. Some modern equipment even allows such changes to be visualized, and values and diagrams to be exported for further processing. This usage of technology in science education is beyond the scope of the present chapter. The chapter focuses on a higher level of technology integration, namely how to set up and manage collaborative platforms using appropriate models and methods. Teachers' major concerns in using technology, especially wikis, arise from their insecurity about the quality of the created artifacts, that not every student learns exactly the same content and may not participate equally in content creation, as well as their fear of not having sufficient IT skills to prevent loss of data (König and Hodel 2013). The examples included show how such pitfalls can be minimized and how twenty-first century skills can be taught not only in science education but also in all other topics from primary school to university level.

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