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The project-based method for a competence-based approach: Teaching computer science in Italian secondary schools

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Abstract

The competence-based approach to education has been found to be effective for teaching. Some countries have adopted it and subsequently reshaped the school system accordingly. Introduced in Italian secondary schools in 2010 by the Ministry for Education, the competence-based approach has only been partially adopted in the classes. Our research aims at discovering solutions to support the adoption of this approach for teachers in Italian secondary schools. A two steps approach has been investigated: 1) inclusion of teachers in the process of competence definition, and 2) support of teachers activity during student projects. The study focuses on computer science teachers, who often teach using the student projects. A software system for a participated definition of competences has been set up. A training course has been designed and implemented. Some student projects have been studied through teacher and student observation in the classroom and in laboratory. The results indicate a weak commitment on the part of teachers towards the competence-based approach. At the same time, exploiting students projects towards the project-based learning method encourages teachers to adopt a competence-based approach, provided the projects are carefully designed and effectively managed.

Chapter 1

Introduction

The competence-based approach to teaching has been supported by educational research (Weinert, 1999), (Delamare Le Deist & Winterton, 2005), (Winterton, 2009), and by international institutions, such as the European Parliament, Council, and Commission.

Research has clarified that the concept of competence mainly refers to individual aspects and, as individual development takes place primarily at school, the concept of competence deserves to be respected as an important part of educational study (Weinert, 1999). At the same time, other researches proposed a holistic model of competence, introducing a comprehensive vision of the competence-based approach (Delamare Le Deist & Winterton, 2005). This vision suggests that several aspects of previous approaches to teaching should change, for example the idea of a time-bounded qualification process and the idea of learning which separates content and context. On the one hand, focusing on “the notion of progression” (Winterton, 2009, p. 688) can help to supersede the time-bounded learning process. On the other hand, learning in context could substitute the “'traditional' lecture approach [*that*] did little to provide learners with a context for the content”, just when “the rapidly changing knowledge base” is “driving changes in both theory and practice” (Savery, 2006, p. 10).

One after another, international institutions have attempted to define the key competences necessary for a successful life and a well-functioning society (OECD (Organisation for Economic & Co-operation and Development), 2005). European institutions have recommended member states to adopt the key competences defined in the European reference framework for lifelong learning (European Parliament & Council of the European Union, 2006), recently renewed by the Council of the European Union (Council of the European Union, 2018), as well as advocating national strategies and a more comprehensive approach (European Commission/EACEA/Eurydice, 2012).

Nevertheless, the practical adoption of this approach has not been carried out homogeneously. Some countries have reshaped their school curricula in order to conform to a competence-based approach. Germany is one of these countries. In 2003 and 2004 educational standards were introduced in Germany, which defined the core learning outcomes in terms of competences for grade 4, in addition to the bottom end of lower secondary education at grade 9 or 10 (Köller & Parchmann, 2012). The subjects involved were biology, chemistry, English, French, German, mathematics, and physics. A proposal of educational standards has also been published for informatics in lower secondary education by the German Informatics Society (GI) in 2008 (Linck et al., 2013, p. 85). Educational standards published in the USA, revised by the Computer Science

Teachers Association (CSTA) in 2011, enforce the computer science (CS, also named Informatics) competence throughout primary and secondary schools.

The process of building a curriculum for all subjects consistent with the competences definition can be put into place by educational institutions. This is referred to as the *institutional way*. An example of this process is given by the school system in Austria (Micheuz, 2016).

In Italy, the reform promoted by the Ministry for Education (MIUR, 2010c) prescribed the institutional adoption of the competence-based approach, subsequently introducing the lists of competences for technical schools (MIUR, 2012a) and for vocational schools (MIUR, 2012b) (in Italian, *professionali*). The learning outcomes for each discipline of the different course years are defined in terms of competences, contents, and skills. However, the reform does not suggest any practical solution for integrating the recently introduced competences and the contents in the class. As a consequence, schools and teachers have to design and create their own procedure for integrating these competences into their curricula.

Moving from theory to a practical method of using, the operationalisation of the competence-based approach is a complex procedure and it is not popular in classes. This low level of popularity (Mulder, 2017, p. 363), (Bottani, 2007) has also been recorded by the CS teachers included in our study sample.

A considerable amount of researchers have worked toward defining the term competence itself and have explored its meaning and implications, but unfortunately the study related to the adoption of this approach in the classes has not yet received adequate attention. An *institutional way* to the adoption of the competence-based approach could well be successful in Italy as well, but the Italian guidelines offer only a weak connection between competences and curriculum. As a consequence, the Italian institutional reform has not worked to change and achieve the competence-based paradigm.

The purpose of this phd research project is to discover solutions to support the adoption of the competence-based approach to education (CBE) for CS teachers in Italian secondary schools. The following research questions have been defined:

I. Are CS secondary school teachers encouraged to adopt the CBE approach when they are involved in the definition of the set of competences?

II. Are CS secondary school teachers induced to adopt the CBE approach when they are applying the project-based learning (PBL) method?

In order to give an answer to the first research question, we planned and designed a system to support the customisation of competences, allowing teachers to give their own definitions of CS competences and analysed its impact.

In order to answer the second research question, we designed and defined two different studies. Firstly, proposing an action-research course we supported CS teachers in Italian secondary schools to use the PBL method in their classes. At the same time, we analysed the use of projects in their teaching, reflecting with the teachers how the application of the PBL method could impact the adoption of the competence-based approach in the classes. The goal was to help the teachers identify target competences when designing the activities for student projects. Secondly, we analysed the ordinary PBL activities of CS teachers in class through six case studies.

To build up an adequate frame for our investigation, the main elements related to our general reference framework were identified in the literature, represented by the competence-based approach and by the project-based learning method.

The structure of this thesis includes six chapters. The state of the art has been described in Chapter 2 and Chapter 3. Chapter 2 introduces the controversy over the concept of competence and describes the state of art of the competence-based approach to education (CBE) which became popular in recent decades. The chapter explores some relevant aspects of this alternative approach to the traditional scheme of “reproduction of accumulated knowledge”: theoretical foundations and applications in different education systems are included. The chapter closes with details on Italian secondary schools and narrows the focus on CS competences in Italian secondary schools.

The CBE approach requires the learning process to develop the competences of the learners. Chapter 3 describes the inductive teaching methods, which are supposed to be effective in activating such a learning process: six relevant inductive teaching methods are described. One of these methods, the project-based learning (PBL), is analysed in detail as one of the goals of this thesis is to investigate whether exploiting the PBL method encourages CS teachers to adopt the CBE approach.

Chapter 4 defines the research problem and the purpose statement. Although the Italian Ministry for Education (MIUR) provided a formal prescription of CBE for Italian secondary schools, as seen in Chapter 2, no official data are available regarding its application in schools. The subsequent limited adoption of the CBE among Italian teachers provides our research problem. This gap between an official requirement to use a CBE approach and the actual situation prompted to the present search for practical support for CS secondary school teachers in adopting the CBE approach. The chapter subsequently focuses on the two research questions of this phd research project.

The final part of Chapter 4 describes the research methods used to address the research questions. In order to promote and to observe the process of defining the competence for CS we developed a software system named CoMaK, which stands for Competence Maker, for a participated definition of competences. The investigation of PBL teaching action involved two studies, firstly defining related methods and contexts: an action-research course, and a collective case study of PBL activities.

Chapter 5 describes the design and the final version of CoMak. Results highlight that the teachers used the functionalities provided by CoMak after the action-research course only to submit a proposal for the definition of a new competence and to simulate the miniforum. Nevertheless, a possible application has been drawn up and other potential participants and users have been listed in the final section of the chapter.

Chapter 6 describes the two studies conducted into PBL activities, created to observe CS teachers: the action-research course, and six student projects. The details of specific methods for each study have also been included, with the results closing the chapter.

Chapter 7 looks at the results of all the activities of our research, with the main result beeing that CS teachers use student projects with their pupils, even though activities are not fully compliant to the PBL method. Furthermore, in some cases the specific competences of the CS discipline are not the focus of student projects, neither in design nor in assessment. The chapter highlights also the possible impact of the research, going on to describe future implications and open questions, including the conclusions.

Chapter 2

Competence-based approach to education

We introduce here the CBE, firstly summarizing the theory and then drawing a picture of the situation on the ground. We briefly highlight the role of disruptive innovation that the competence based approach could play, according to many researchers, educators and institutions. "CBE is a popular innovation [...] because the expectations are that it makes education more authentic and attractive for students" (Wesselink, Biemans, Gulikers, & Mulder, 2017, p. 533). Consequently this innovation might deeply change the education systems, because it "requires the hard work of designing a wholly new teaching and learning model on the ground" (Freeland, 2014, p. 21).

Most activities of many education systems have been built on the classic educational scheme of the "reproduction of accumulated knowledge". According to this traditional model, teachers just have to impart their knowledge to the learners, and thus enable students to fill their own brains with contents and notions. As Unesco OECD highlights in the survey "*Definition and selection of key competencies: executive summary*" in 2005, the knowledge society needs to move "beyond taught knowledge and skills [...] well beyond the basic reproduction of accumulated knowledge" (OECD (Organisation for Economic & Co-operation and Development), 2005, p. 8).

Section 2.1 describes the theoretical foundations of the competence-based approach. Different classifications and principles of the competence theory are discussed with the aim of offering an exhaustive picture of the "fuzzy concept" of competence, citing (Boon & van der Klink, 2002) from (Delamare Le Deist & Winterton, 2005, p. 29). The concept of competence has been discussed "in various domains, such as in psychology, education, performance management and corporate strategy" (Mulder, 2017, p. 3), and research on the competence-based approach has been developed in organisational and in pedagogical fields. Furthermore, the concept has been used in almost seven different ways, according to (Weinert, 1999).

The definitions of some relevant terms in the context of the "competence" discussion are also analysed. This terminology has paved the way for a joint study of teaching and learning, even though they are separate activities. As a consequence, we will use the comprehensive term "education" to refer to both teaching and learning.

Subsequently, the role of various educational institutions is described, focusing on recent initiatives to promote the adoption of the fundamentals of the CBE and to introduce them into education systems. More details are given to distinguish general competences, appropriate for all citizens, and specific competences, connected to the different disciplines. This section also anticipates some aspects regarding competences for the computer science discipline (CS for short), discussed in section 2.3.

Following this section 2.2 focuses on the Italian education system, detailing the main steps of the reform that introduced an explicit inclusion of the competences in secondary schools.

Finally, section 2.3 explores the competences for the discipline of CS in depth, focusing on Italian secondary schools.

2.1 Theoretical context of the competence-based approach to education

The first part of this section shows the theoretical basis of the CBE approach and the reasons and motivations underpinning it. The second part includes some definitions of the most common terms used in the field, moving on to highlight the distinction between key competences, also called basic or general competences for citizens, and domain-specific competences, focusing on CS competences. Finally the section describes some issues regarding the relationship between CBE and curricula, and the opportunities provided by studying for and obtaining certification.

2.1.1 Main principles of the competence-based approach to education

In order to introduce some relevant issues from the vast field of pedagogy, we describe the most important families of pedagogical theories. Further on, this will help to explore the concept of competence.

2.1.1.1 Pedagogical theories

Many theoretical pedagogical approaches have been developed. Following the track depicted in (Anderson, 2008), we focus on three relevant theories of learning: behaviourism, cognitivism and constructivism.

Behaviourism. According to Anderson, behaviourism is grounded on objectivism as reality is considered to be objective, external to the individual. As a consequence, we can only know the facts of reality, and knowledge can be gained only through perceived experience. The external environment changes learners' behaviour; the behaviour is an observable fact; then, learning can be measured, observing the changes in behaviour of the learner. In this scheme, the teacher defines a learning objective, with respect to the personal instruction and the subjective behaviour of the learner, whereas the focus is on the content. Nobody can say anything about “what is going on in the learner’s head” (Anderson, 2008, p. 19)[1].

Cognitivism. Flavell claims that cognitivism is the learning process resulting in, among other factors, observable changes in behaviour, because the learning outcomes depend on individual interpretation of reality. Personal characteristics of the individuals influence their internal process of learning, because previous experiences and knowledge, processing capacity, as well as cognitive efforts contribute to affect the capacity of knowledge acquisition. According to

1 Watson, Thorndike, Pavlov, and Skinner are among the authors cited here.

this approach, the learning process involves also the meta-cognition of the learners, that is "their knowledge and cognition about cognitive phenomena" (Flavell, 1979, p. 906).

Constructivism. According to this theory, learning is the process able to build the knowledge of the individuals who are trying to understand the world, in a certain social and cultural environment. Construction of personal knowledge depends on the individual situation, and follows three steps: observation of the world, processing of the collected information, and interpretation, that is the re-construction of the previous knowledge of the learners. Learning outcomes can be obtained when the learners have a context in which they can apply what they have learnt. The learning process is rooted or situated in "the context and in the specific contents of the activities which generate it" (in (Castoldi, 2011, p. 28), translated from Italian). "In particular, the knowledge is acquired for a recognizable personal purpose", and "Thinking about thinking turns the child into an epistemologist" (Papert, 1980, p. 21). Constructivist teachers maintain the role of leadership and guide, with the aim of "encouraging and orienting the students' constructive effort" (Glasersfeld, 1990, p. 26)[2].

The principles of the constructivist approach to the learning process are the basis for an education system addressing competences development.

2.1.1.2 The concept of competence

The competence-based approach to education is promoted as an effective way to learning and teaching in many countries of the world and at different levels. Besides education, the term competence has been used in a broad set of disciplines and contexts. Unfortunately, the variety of related meanings is so vast that "it is impossible to identify or impute a coherent theory or to arrive at a definition [*of competence*] capable of accommodating and reconciling all the different ways the term is used" (Winterton, Delamare-Le Deist, & Stringfellow, 2005, p. 7). Nevertheless, some relevant definitions of the concept of competence are clearly summarized in (Winterton et al., 2005), and several points can be accepted as established. To clarify these points further we also describe some misunderstandings recurrent in the field.

Focusing on European countries, the competence-based approach was adopted after 1980 in the education system of three countries, mostly to deal with vocational issues.

The vocational training sector in UK introduced a competence-based qualification system, even if the model of competence-based education and training (CBET), promoted by institutions, prompted criticism from various authors. Among these, Hyland argues that competence systems "are concerned only with the accreditation of performance outcomes, not with processes of learning and development" (Hyland, 1997, p. 495). Moreover, the author dismisses CBET as "dominated by behaviourism and work-based functional analysis" (Hyland, 1997, p. 499).

In France, the adopted model of competence was built around the famous triad of *savoir* (knowledge), *savoir-faire* (functional competences) and *savoir-être* (behavioural competences). This approach is more inclusive than the British one.

The German vocational curricula were mainly built around the subjects (learning inputs), and knowledge and skills were strongly job-oriented. The reform of 1996 restructured the curricula in learning fields (*Lernfelder*), rather than in occupational terms. Curricula were described by vocational "action competence", which specifies domain competence, personal competence and social competence.

2 Where the author refers to the Piaget's theory.

A summary of the many aspects of the concept of competence has been proposed in (Delamare Le Deist & Winterton, 2005), as reported in (Pikkarainen, 2014). According to Pikkarainen, "competence" is "a concept which contains and somehow balances different sides of an individual person's abilities and capabilities such as skills, attitudes, and cognitive functions" (Pikkarainen, 2014, p. 625), the three competences also traditionally known as knowledge, skills, and attitudes (KSA).

A more comprehensive view of the competences is offered by the multidimensional model, also referred to as a holistic model of competence (Winterton, 2009, p. 691). Besides the cognitive, functional and social dimensions of competences (KSA), the holistic model includes the meta-competence, that is the personal competence which makes individuals aware of their own competence.

The holistic model has also been represented as a tetrahedron, shown in the 3D Figure 1. This solid figure, in which three faces represent respectively knowledge, skills, and attitudes, intends to

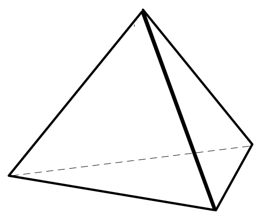


***Figure** 1: The holistic tetrahedron, redrawn from (Delamare Le Deist & Winterton, 2005)*

highlight that the meta-competence, the fourth face, has to be based on the other three, more traditional competences. According to the authors, the tetrahedron model reflects "the unity of competence and the difficulty of separating cognitive, functional and social dimensions in practice" (Delamare Le Deist & Winterton, 2005, p. 40). The identification of the competence does make sense only if we are able to comprehend all the four different aspects, or characteristics, represented by the four faces: the cognitive competence, the functional competence, the social competence, and the meta-competence.

According to (Delamare Le Deist & Winterton, 2005, p. 39), table 2.1 classifies the four dimensions of the holistic model of competence into conceptual and operational dimensions (the horizontal rows) and into occupational and personal dimensions (two columns).

Table 2.1: A multidimensional model of competence, authors elaboration on (Delamare Le Deist & Winterton, 2005)

	Occupational	*Personal*
Conceptual	**Cognitive competence** (knowledge, *savoir*)	**Meta-competence** (learning to learn)
Operational	**Functional competence** (applied skills, *savoir-faire*)	**Social competence** (behaviours, attitudes, *savoir-être*)

The CBE approach discards the "rigid canon of knowledge in specific subjects passed on from generation to generation" (Klieme, Hartig, & Rauch, 2008, p. 3), because the holistic model requires observation of the competence from the four different points of view, in order to depict it effectively. This change suggested by the CBE approach has also had a relevant impact on the theoretical basis of the education systems, because it "challenged education to step out of its comfort zone, away from memorising textbooks and doing reproductive tests, and to think outside in" (Mulder, 2017, p. 3). According to the CBE approach, the learner can also be seen from a different perspective. The main goal of the CBE is to help learners in developing and building their own competences.

An issue arises from the two words “competence” and “competency”, with the related plurals. In some cases, the two terms seem to be used as synonyms. At the end of the 1950s the term “competence” was used by White (White, 1959), with the broad meaning, derived by biology and then relevant also to a human subject, of “capacity to interact effectively with its environment” (White, 1959, p. 297). Learning can help to preserve the results of reciprocal effects of interaction between the individuals and the environment: in this way, the competence of the individuals to deal with the environment might increase.

McClelland uses the two terms “competence” and “competency” in (McClelland, 1973), where the author deals with the issue of assessment in job recruitment. According to Winterton, “McClelland, like White, originally used the term competence and only later adopted the term competency, without any change in meaning” (Winterton, 2009, p. 683).

On the other hand, other authors associate each term to a specific concept, highlighting the differences. According to these, the word “competency” represents the personal characteristics of an individual, enabling them to perform in a context, typically in a job situation. For this reason the term “competency” has been also referred to as an *input* element. This term is associated with an American use. On the contrary the term “competence” is on the side of the job applications, because it is “what a person needs to know and be able to do in order to undertake the tasks associated with a particular occupation” (Winterton, 2009, p. 684). Consequently the term “competence” has also been referred to as an *output* element. The term responds to a British use. Table 2.2 summarizes the differences between the two terms; the table, derived by (Winterton, 2009), shows also two short lists of authors, associated to the use of the two terms.

Table 2.2: Competency & Competence, authors elaboration on (Winterton, 2009)

Competency	**Competence**
Input	Output
Attributes a person must acquire	Demonstration of individual attributes in performance
Prevalent in USA	Prevalent in UK
Boyatzis, Klemp, McClelland, Spencer	Knasel, Mansfield, Meed, Miller, Mitchell

“Distinguishing competency and competence in terms of input [*versus*] output”, as suggested in (Winterton, 2009, p. 684), “one could plausibly postulate input [*versus*] output measures for each dimension of competence”. Accordingly, we could postulate six measures of competence combining the three traditional dimensions of cognitive, functional and social competence with the input/output distinction (Table 2.3).

Table 2.3: Six plausible measures for competence, authors elaboration on (Winterton, 2009)

	Input	*Output*
Cognitive	intelligence	knowledge
Functional	dexterity	skills
Social	attitudes	behaviours

For example, the cognitive dimension can be measurable in terms of competency, observing the "intelligence", and in terms of competence, observing the "knowledge" of a person.

Even if "competency" is the term prevalent in the USA while "competence" prevails in UK, the distinction between the American use and British use oversimplifies the situation. First of all, there are different models both in American and in British literature and tradition. Then, in the different countries of the two geographical areas there are specific characteristics as well.

Notwithstanding the foregoing definitions and sharp distinctions, "the terms competence and competency are frequently conflated and used interchangeably" (Winterton, 2009, p. 684).

2.1.2 Terminology

We summarize and clarify here the main terms connected to the competence concept and frequently used in the thesis, in order to avoid ambiguity.

Learning outcomes. "Statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence" (Union, 2008, p. C 111/4).

Competence. "Abilities and capabilities such as skills, attitudes, and cognitive functions" of an individual person's (Pikkarainen, 2014, p. 625); "a combination of knowledge, skills and attitudes" (Council of the European Union, 2018, p. 14)[3]. Two more definitions of CEDEFOP similarly say: "ability to apply learning outcomes adequately in a defined context" or "ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 47). Subsection 2.1.1.2 provides details regarding the competence concept, including some comments on the ambiguity brought by two forms of the term: competence and competency.

Knowledge. "Outcome of assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices related to a field of study or work" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 147).

Skill. "Ability to apply knowledge and use know-how to complete tasks and solve problems" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 227).

3 The previous Recommendation on key competences by European Parliament and Council defined competence as "a combination of knowledge, skills and attitudes appropriate to the context" (European Parliament & Council of the European Union, 2006, p. 13).

Assessment vs Evaluation. Assessment is a "process of appraising knowledge, know-how, skills and/or competences of an individual against predefined criteria […] *Assessment* generally refers to appraisal of individuals whereas *evaluation* is more frequently used to describe appraisal of education and training methods or providers" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 28). The term *evaluation* might be applied for example in "evaluation of education and training", meaning a "judgement on the value of an intervention, training programme or policy with reference to criteria and standards (such as its relevance or efficiency)" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 97).

2.1.3 Key competences

We introduce the distinction between general and specific competences, referring to the set of competences for European citizens which the European institutions defined in 2006 (European Parliament & Council of the European Union, 2006), renewed by the Council of the European Union in 2018 (Council of the European Union, 2018). Even though they have been defined the "key competences for lifelong learning", related to all the citizens rather than specific for the schools, the first recommendation asks member states to work with the aim of ensuring that the "initial education and training offers all young people the means to develop the key competences to a level that equips them for adult life" (European Parliament & Council of the European Union, 2006, p. 11). Nevertheless, the European recommendation does not include any kind of binding prescription for the member states, in this way accepting and respecting the differences among the school systems. It offers a common European reference tool, called Reference Framework, in order to support the member states to "develop the provision of key competences for all as part of their lifelong learning strategies, including their strategies for achieving universal literacy" (ibidem, p. 11). The cited Reference Framework was enriched in 2008 with the European Qualifications Framework (eQF) for lifelong learning, which describes competence "in terms of responsibility and autonomy" (Union, 2008, p. C 111/4).

The European recommendation defines competence "as a combination of knowledge, skills and attitudes appropriate to the context" (European Parliament & Council of the European Union, 2006, p. 13), setting out the eight European key competences:

1) Communication in the mother tongue
2) Communication in foreign languages
3) Mathematical competence and basic competences in science and technology
4) Digital competence
5) Learning to learn
6) Social and civic competences
7) Sense of initiative and entrepreneurship
8) Cultural awareness and expression

The European Reference Framework, as updated in 2018 by the Council of the European Union (Council of the European Union, 2018) partially rewriting the previous list, defines a new set of the eight European key competences:

1) Literacy competence

2) Multilingual competence

3) Mathematical competence and competence in science, technology, and engineering

4) Digital competence

5) Personal, social and learning to learn competence

6) Citizenship competence

7) Entrepreneurship competence

8) Cultural awareness and expression competence

In both the recommendations, the definition of the concept of competence recalls that the holistic principle is the basis of the CBE approach. Both personal and social aspects of competences development are referred to here, and not only as an introductory statement and general declaration. As a matter of fact, they have been detailed as well in the further section of the Recommendation, where we can find that personal and social attitudes are often combined, as expected. For example the entrepreneurship competences is strictly related to individual goals and attitudes, such as motivation, but it requires also social skills, to enable collaborative activities. Even though the eight competences "overlap and interlock" in some essential aspects, the recommendation supplies the definition of all the competences, then adding more details to each of them with the "essential knowledge, skills and attitudes related" parts.

Among the eight key competences, digital competence is considered a priority to ensure the digital inclusion into the knowledge society, for the European citizens. As a result, a meaningful prevalence has been given to "the confident and critical use of Information Society Technology (IST) for work, leisure and communication" (European Parliament & Council of the European Union, 2006, p. 15). As described by the last recommendation, "digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" (Council of the European Union, 2018, p. 20). No technical attitudes underpin digital competence defined by the European recommendation, which tries to draw the characteristics of an evolving society through the characteristics of the common, future citizen, rather than of a computer geek. Also the European DIGCOMP project proposed a digital competence framework in (Ferrari, Punie, Brečko, Joint Research Centre, & Institute for Prospective Technological Studies, 2013), with the goal of supporting the development of this competence by all the European citizens. As we will explain below, digital competence is not the focus of the thesis.

2.1.4 Computer Science competences

The competences of the single subject disciplines are also named subject-specific or domain-specific competences. For example CS competences are subject-specific, directly related to the CS discipline, whereas digital competence is one of the key competences.

The domain competences for some disciplines has already been pointed out. For example the TUNING project (Tuning Educational Structure in Europe, 2016) is concerned with subject-specific competences but limited to the higher level of education, also called tertiary education, which includes the University level. The TUNING project, born in Europe in 2000, is now spread around the world, recently acquiring more continental branches. The project has been also divided in parts, related to specific subject-areas and therefore to the subject-specific competences. One of the parts is the FETCH initiative (FETCH Project (Future Education and Training in Computing), 2016), which focuses on CS competence, at the level of tertiary education.

For the upper secondary schools, between the lower secondary schools and the University level, only a few initiatives provide a meaningful guideline to define the CS competences for grade 11 to 12 (grade 13 in Italy, and in few others European states). The following part of this section illustrates two initiatives of the education systems in two countries, USA and Germany. We focus on USA and Germany for various reasons. The authoritative organisation of the USA system has a large impact. To define the domain competences, the starting point are concepts and contents on the basis of the discipline. To this goal we describe the K12 CS Framework, which identifies the CS core concepts and provides the "baseline competencies" for CS in USA. The education system in Germany defines a very detailed list of CS competences. Furthermore, the German vocational school system has brought the contribution to define personal and social competences with the "action competence" (subsection 2.1.1.2, page 15).

We acknowledge that comparing various education systems requires an in-depth analysis and a variety of tools. For example the Darmstadt Model has been proposed to this goal. The model, initially thought to compare the research results in CS education (Hubwieser, 2013), has then been implemented by the researchers as a "unifying framework" for the K-12 CS education studies (Hubwieser, Armoni, Giannakos, & Mittermeir, 2014). On the other hand investigating the education systems of different countries is not a goal of this thesis.

CS competences in USA. In 2011 the publication of CS standard revised by the Computer Science Teachers Association (CSTA) task force offered a meaningful and authoritative contribution "to strengthen computer science fluency and competency throughout primary and secondary schools" (CSTA (Computer Science Teachers Association), 2011, p. ii). The task force had the opportunity to observe the lack of CS in USA K-12 education. Consequently its report promoted the adoption of the subject CS by educational institutions of American states, highlighting the relevance of CS for all the citizens in the 21st century society. The CS standard of educational institutions of USA did not propose a formal introduction of the CBE approach.

In 2016 was published the K12 CS Framework, led by the Association for Computing Machinery, Code.org, Computer Science Teachers Association, Cyber Innovation Center, and National Math and Science Initiative in partnership with states and districts (K-12 computer science framework, 2016). The framework was offered to meet the society needs, with the aim at providing "a unifying vision to guide computer science from a subject for the fortunate few to an opportunity for all" (K-12 computer science framework, 2016, p. 4). "The *K12 Computer Science Framework* was developed for states, districts, schools, and organizations to inform the development of standards and curriculum, build capacity for teaching computer science, and implement computer science pathways" (K-12 computer science framework, 2016, p. 1). The framework identifies 5 core concepts, 5 crosscutting concepts, and 7 core practices (Table 2.4). Whereas core concepts represent major contents areas in the CS field, crosscutting concepts offer thematic connections among different core concepts. Lastly, core practices represent behaviours which help students to wholly become involved in the core concepts of CS.

Table 2.4: Concepts and practices of the K-12 CS Framework, authors elaboration on (K-12 computer science framework, 2016, p. 152)

Core Concepts	**Crosscutting concepts**	**Core Practices**
1. Computing systems 2. Networks and the	1. Abstraction 2. System relationships	1. Fostering an inclusive computing culture 2. Collaborating around computing

internet 3. Data and analysis 4. Algorithms and programming 5. Impacts of computing	3. Human-computer interaction 4. Privacy and security 5. Communication and coordination	3. Recognizing and defining computational problems 4. Developing and using abstractions 5. Creating computational artifacts 6. Testing and refining computational artifacts 7. Communicating about computing

The framework groups the K-12 grades into 4 grade bands: K-2, 3-5, 6-8, and 9-12. The framework is fully accessible at https://k12cs.org/ Url, offering three different views: by grade band, by progression, and by core concepts. Practices are displayed firstly, and for each of them a statement declares the practical goals students should achieve after grade 12, as well as describing in a narrative format how the students could progress during their development of the practices. Then each core concept is articulated into subconcepts, and each subconcept has been explained by a concept statement, which describes "conceptual milestones at different grade bands endpoints" (K-12 computer science framework, 2016, p. 60).

The framework does not identify learning outcomes for students and schools of various grade bands. Nevertheless, concepts and practice statements represent "the big ideas that students should understand by the end of a grade band". Even though these "big ideas" do not include all of the learning of the grade band, they should constitute the "baseline competencies" for education system (K-12 computer science framework, 2016, p. 151).

The framework foreran and stimulated the definition of CS standards, like the CS standards revised in July 2017 by the CSTA task force (CSTA (Computer Science Teachers Association), 2017).

CS competences in Germany. The CS competences for secondary schools are the main focus of the research project Measurement Procedure for Informatics in Secondary Education (MoKoM), promoted in Germany since 2008 by the German Research Foundation (DFG) (Neugebauer, Magenheim, Ohrndorf, Schaper, & Schubert, 2015). Three relevant output of the project are cited here: the competence structure model, the measurement instrument, and the competence level model. The competence structure model is dedicated to two sub-domains of the CS education[4]: informatics modelling and system comprehension (Linck et al., 2013). The construction of the structure model started from a theoretically derived competence model, which subsequently has been refined through an empirical research. The contributions of the experts engaged in the empirical research helped to define a structure with five competence dimensions: K1 System application, K2 System comprehension, K3 System development, K4 Dealing with system complexity, and K5 Noncognitive skills. Each dimension has been detailed in a number of competence components, and for each component the different competence facets have been listed, as shown in Tables 2.5, 2.6, 2.7, 2.8, and 2.9[5]. Even though the model introduces a high level of granularity in defining the competences, nevertheless many competences have quite clear reference or relation to other competences, both of the same and of a different dimension.

4 The model can be extended, covering a wider set of sub-domains. An example of test items in the sub-domain of logic programming is given in (Linck, 2013).

5 The original tables, presented in (Linck et al., 2013) at pages 87 to 90, show separately the five competence dimensions.

Table 2.5: Competence dimensions K1 – System Application, by (Linck et al., 2013, p. 87)

K1 System Application

K1.1 Structuring of application field
    K1.1.1 Structure problems
    K1.1.2 Apply appropriate tools for structuring
        K1.1.2.1 Apply Top-Down design
        K1.1.2.2 Apply Step-wise Refinement
    K1.1.3 Appropriately apply system functions
K1.2 System exploration
    K1.2.1 Systematically explore system functions
    K1.2.2 Identify structural properties
    K1.2.3 Develop mental models
K1.3 System selection
    K1.3.1 Analyze system functions
    K1.3.2 Select applicable systems for a problem
        K1.3.2.1 Compare systems
        K1.3.2.2 Know & apply appropriate selection criteria
        K1.3.2.3 Evaluate usability & efficiency of systems
        K1.3.2.4 Develop new selection criteria
K1.4 Use of media to foster system application
    K1.4.1 Evaluate systems with media
        K1.4.1.1 Evaluate differences of digital & traditional media
    K1.4.2 Appropriately use media for programming
    K1.4.3 Read & write informatics' terminology
K1.5 Transfer to new application fields
    K1.5.1 Identify and transfer fundamental ideas & concepts

Table 2.6: Competence dimensions K2 – System comprehension, by (Linck et al., 2013, p. 87)

K2 System comprehension

K2.1 System requirements
    Analyze & evaluate system requirements
K2.2 Systematic tests
    Systematically test systems
    K2.2.1 Analyze errors to enhance tests
    K2.2.2 Apply established test strategies
K2.3 System exploration
    Independently explore systems
K2.4 Evaluation of software quality
    Evaluate quality of software
    K2.4.1 Evaluate correctness
    K2.4.2 Evaluate efficiency
    K2.4.3 Evaluate robustness
    K2.4.4 Evaluate reusability
    K2.4.5 Evaluate compatibility
    K2.4.6 Evaluate structuredness
    K2.4.7 Evaluate usability
    K2.4.8 Evaluate maintainability
    K2.4.9 Evaluate information security
K2.5 Architecture & organization
    Know & analyze architecture & organization
K2.6 Algorithms & data structures
    Know & evaluate algorithms & data structures
    K2.6.1 Know & apply algorithms
    K2.6.2 Know & apply data structures
K2.7 Informatics' Views
    K2.7.1 Know & use External View
    K2.7.2 Know & use Internal View
    K2.7.3 Apply Change of View

Table 2.7: Competence dimensions K3 – System development, by (Linck et al., 2013, p. 88)

K3 System Development

K3.1 Software development process models
    Know & apply of software development process models
K3.2 Business Modeling
    K3.2.1 Identify & document business processes
K3.3 Requirements
    K3.3.1 Select platforms/technologies
    K3.3.2 Identify & describe use cases
    K3.3.3 Identify functional requirements
    K3.3.4 Develop activity diagrams
    K3.3.5 Document functional requirements
K3.4 Analysis
    K3.4.1 Know & apply object-oriented terminology
    K3.4.2 Execute object-oriented decomposition
    K3.4.3 Develop analysis UML diagrams
        K3.4.3.1 Develop CRC-Cards
        K3.4.3.2 Develop object diagrams
        K3.4.3.3 Develop sequence diagrams
        K3.4.3.4 Develop analysis class diagrams
K3.5 Design
    K3.5.1 Select architectures
    K3.5.2 Know & apply design patterns
    K3.5.3 Design interfaces
    K3.5.4 Develop design UML diagrams
        K3.5.4.1 Develop design class diagrams
        K3.5.4.2 Develop state diagrams
        K3.5.4.3 Develop deployment diagrams
K3.6 Implementation
    K3.6.1 Know & use object-oriented programming
    K3.6.2 Know & use programming languages
        K3.6.2.1 Implement programming concepts
        K3.6.2.2 Transform class diagrams to source code
        K3.6.2.3 Integrate libraries
    K3.6.3 Know & use tools (IDEs)
    K3.6.4 Know & use versioning software
    K3.6.5 Document source code
    K3.6.6 Integrate software modules
K3.7 Test
    K3.7.1 Systematically test software
        K3.7.1.1 Develop test plans
        K3.7.1.2 Know & apply of test models
        K3.7.1.3 Identify test cases
        K3.7.1.4 Automatically execute tests
K3.8 Iterative development
    K3.8.1 Select modeling techniques
    K3.8.2 Select appropriate software engineering workflows

For example, the comprehension of the inner workings of informatics systems might require to identifying architectural structures (dimension K2), which in turn requires the knowledge of development processes (dimension K3) (Linck et al., 2013, p. 89). Similar considerations could be provided for the requirements analysis, both included in dimension K2 and K3.

Table 2.8: Competence dimensions K4 – Dealing with system complexity, by (Linck et al., 2013, p. 89)

K4 Dealing with system complexity
K4.1 Measures of complexity: Time & Space
Know & evaluate measures of complexity
K4.1.1 Know & evaluate static complexity
K4.1.2 Know & evaluate dynamic complexity
K4.1.2.1 Estimate runtime & memory usage
K4.1.2.2 Compare & select algorithms
K4.2 Number of components
K4.2.1 Identify & exemplify components
K4.2.2 Verify components
K4.2.3 Design components
K4.3 Level of networkedness
K4.3.1 Use cross linked information
K4.3.2 Comprehend cross linked systems
K4.4 Stand-alone vs. distributed systems
K4.4.1 Compare stand-alone & distributed systems
K4.4.2 Design distributed systems
K4.5 Level of human-computer interaction
K4.5.1 Appropriately select the level of HCI to use
K4.5.2 User centric design of HCI
K4.6 Combinatorial complexity
K4.6.1 Detect & comprehend combinatorial complexity in tests
K4.6.2 Estimate & apply combinatorial complexity in tests
K4.6.3 Identify & select appropriate test cases

The MoKoM research project also introduced a measurement instrument. A set of 74 test items was initially built up, covering almost all the competences of the structure model. Then, the test items were collected in six booklets, adapting the instrument to the real class needs and settings. To study the reliability of the measurement instrument, a big sample with more than 500 datasets of the students' answers to the booklets tests was collected and analysed. The analysis drew out a list of difficulty criteria or aspects "concerning informatics specific difficulty facets" (Neugebauer et al., 2015, p. 47).

The third relevant result of the MoKoM project, the competence level model, required the definition of thresholds or anchor points for the competence assessment, to differentiate individual proficiency levels. At the end of this phase, four proficiency levels have been defined: from level A to level D, "with increasing requirements" (Neugebauer et al., 2015, p. 51).

Table 2.9: Competence dimension K5 – Non-cognitive skills, by (Linck et al., 2013, p. 90)

K5 Non-cognitive skills
K5.1 Attitudes K5.1.1 Perceive & Anticipate effects of Informatic Systems K5.1.1.1 Demystify informatic systems K5.1.1.2 Recognize meaningfulness of system application, comprehension and development K5.1.1.3 Assess appropriateness and quality of informatics systems K5.1.1.4 Recognize solvability of informatics systems K5.1.1.5 Know & evaluate consequences of informatics systems for social realities K5.1.2 Expectations for informatics literacy & professional practise K5.1.2.1 Affinity and enthusiasm for informatics issues K5.1.2.2 Willing to face demanding informatics challenges K5.2 Social-communicative skills Recognize social-communicative skills as significant K5.2.1 Cooperation & Teamwork K5.2.1.1 Communicative skills K5.2.1.1.1 Discuss informatics topics K5.2.1.1.2 Present informatics topics K5.2.1.1.3 Able & willing to communicate knowledge K5.2.1.1.4 Able & willing to criticize constructively K5.2.1.2 Cooperation K5.2.1.2.1 Make and fulfill agreements in a team K5.2.1.2.2 Willing to work according to agreements K5.2.1.2.3 Willing to pick up ideas of other team members K5.2.2 Empathy: Ability to change perspectives and roles K5.3 Motivational and volitional skills K5.3.1 Open to new ideas and new requirements K5.3.1.1 Willing to deploy new and unknown informatics approaches K5.3.1.2 Avoid mechanistic informatics approaches K5.3.2 Learning motivation K5.3.2.1 Willing to improve informatics abilities and knowledge K5.3.2.2 Willing to fulfill informatics tasks successfully K5.3.3 Commitment & Engagement K5.3.3.1 Feel obligated to fulfill informatics tasks K5.3.3.2 Exert oneself to fulfill informatics tasks

2.1.5 Competences and curricula

Curriculum is the “inventory of activities related to the design, organisation and planning of an education or training action, including definition of learning objectives, content, methods (including assessment) and material, as well as arrangements for training teachers and trainers” (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 56).

Discussed by the researchers for a long time, “The concept of competence proved extremely resilient arguably becoming *the* defining characteristic of European policies on employment, education and training” (Mulder, 2017, p. 6). The international organizations and institutions proposed a political line which explicitly includes the competence. In 2006 the European Parliament and the Council of the European Union recommended to the member states the adoption of the European key competences (European Parliament & Council of the European Union, 2006).

In the wide range of education systems in Europe, the European Union does not have the role to set or to define the curriculum for the education system of the different member states. The recommendation of the communitarian institutions did not intend to force the educational entities of the member states to comply with an unrealised homogeneous curriculum. The recommendations of the year 2006 might be intended only as a warm invitation, that "encourages and facilitates national reforms and further cooperation" among the member states, leaving "the implementation of this Recommendation to Member States", and offering a support for the national reforms, "by establishing a common reference point" (European Parliament & Council of the European Union, 2006, p. L 394/12), a common orientation toward the CBE approach.

Institutional differences, basically descending from different legislations, and relevant differences of the social environments have to be taken into account for a comprehensive comparison among education systems, which is out the scope of this thesis. There are really meaningful differences among the education systems of different countries and areas, included the European ones. In fact, the education systems of the member states are different under a lot of perspectives. Among these we can firstly cite the number of grades or school-years, where the most common solution is 12 years-grades, even though the 13th grade is present, not only in Italy but also in some of German Länder. Then, we can also consider the number of disciplines which students must take, and the opportunities for a limited or wide choice among disciplines. The education systems are very different because they reflect many social and cultural differences among countries. As a consequence, planning a common curriculum in the schools of the European Union is not under discussion.

As a consequence, when the educational institutions of the European countries decided to gradually acquire the general principles and the theoretical basis of the CBE, they redesigned their own curricula. The countries adopted solutions suited to their social and educational environment, developing curricula which fit the CBE approach to their contexts.

We can cite here two cases in which the CBE research was relevant in the curricula development. In the first case, the MokoM group compared its competence model to the German informatics standards for secondary education, elaborated by an expert group of the German Informatics Society (GI) since 2008 (Magenheim et al., 2013). The German standards define the minimal informatics requirements, which can also been described as basic competences in informatics. This suggested to define an assessment tool for informatics standards, helping to move the educational standards towards outcome-oriented national standards (Linck et al., 2013), and to "encourage the revision of existing standard for computer science education" (Neugebauer et al., 2015, p. 55).

Moving to another German speaking country for the second case, Austrian Ministry for Education provided competence models defining the learning goals (Brunner & Di Angelo, 2014, p. 90) in terms of competences for the different disciplines. As shown in (Micheuz, 2016, p. 29) with the case of the Applied Informatics subject, the competence model lists the contents and includes three levels of competence: knowing/understanding, applying/designing, and reflecting/evaluating. For each content and for each level of competence a descriptor was provided, in the form of "I can ...". In this way, every content has the descriptors for three different levels of competence.

2.1.6 Competences and certification

The certificate is "an official document, issued by an awarding body, which records achievements of an individual following assessment against a predefined standard." (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 41).

The education systems deals with the assessment of the competences. As we said in section 2.1.2, assessment is referred to individuals' knowledge or competences. In order to provide learners a formal recognition, the assessment process "is typically followed by certification" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 28). Usually, certifications are provided at completion of the different stages of a curriculum. Accordingly, "the national qualification systems" implement activities "related to the recognition of learning outcomes", such as "assessment and certification of learning outcomes" (CEDEFOP (European Centre for the Development of Vocational Training), 2014, p. 205). In Italian schools the competence reform introduced the certification named certificate of the basic competences (*Certificato delle competenze di base*, in Italian), at two different grades: for completion of elementary school, 5th grade (MIUR (Ministry for Education - Ministero dell'Istruzione, l'Università, 2012); at the end of the lower secondary school, at completion of the 10th grade (MIUR, 2010a). For the 5th grade certificate guidelines have been defined by the Ministry for Education few years later, claiming that competences and knowledge require to be assessed differently: "if the object to assess is complex, complex has to be as well the assessment process […] which requires time and a systematic observation of students facing different situations" (MIUR, 2015, p. 5).

Besides the certificates of completion or graduation, for example at the end of secondary school, other kinds of certification recognise learning outcomes in various fields and at different levels. Among many kinds of competence certifications, covering a wide range of competences, we mention here foreign language certifications and ICT (Information and Communication Technology) certifications, because of their popularity at the secondary school level, among teachers, pupils, and families. Focusing on ICT, CEPIS[6] and ECDL foundation[7] developed programmes to certificate competences. Examples are the "competence in the use of computers and digital tools to the globally-recognised ECDL[8] standard, known as ICDL worldwide" (ECDL Foundation (European Computer Driving Licence Foundation), n.d.), or the European Certification of Informatics Professionals (EUCIP) (CEPIS (Council of European Professional Informatics Societies), n.d.), a "professional certification and competency development scheme, aimed at informatics professionals and practitioners". AICA (*Associazione Italiana per l'Informatica e il Calcolo Automatico*, in Italian) is the ECDL National Operator in Italy, promoting a lot of initiatives to certify ICT competences for schools, citizens, and professionals. Competences for professionals define the European ICT Professional Profiles according to the e-Competence Framework (e-CF) (AICA (Italian Association for Informatics and Automatic Calculation), 2018).

Furthermore, many proprietary certifications are available in the ICT marketplace. For example the entry-level certification MTA (Microsoft Technology Associate)[9] of Microsoft, or CCENT (Cisco Certified Entry Networking Technician)[10] of Cisco.

A critical point of view has been cited in (Winterton et al., 2005, p. 29), quoting Jeris and Johnson (Jeris & Johnson, 2004) who warn against a possible distortion in the application of some forms of certifications. The distortion consists in a "commodification of competence into certifiable

6 https://www.cepis.org/index.jsp. Council of European Professional Informatics Societies (CEPIS) is a non-profit organisation, the representative body of national informatics associations throughout greater Europe

7 http://ecdl.org/

8 ECDL and ICDL stand respectively for European and International Computer Driving License

9 https://www.microsoft.com/it-it/learning/certification-overview.aspx

10 https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/entry/ccent.html

competencies” which “is disturbing in light of the strong bonds between identifying competencies and tying them to practice standards”.

2.2 Competence-based approach to education in Italian schools

The solution provided in Italy to introduce the CBE approach into the education system was founded on the European Recommendation (European Parliament & Council of the European Union, 2006), with the definition of the eight key competences. The European Recommendation refers to life-long learning, whereas the Italian Ministry for Education (MIUR, 2007) draws the general structure of the competences for the ten mandatory school years of the Italian education system (Ronchetti, 2017).

A relevant role in the Italian structure of the competences is played by the cultural axes, to which knowledge and competences have to be referred, whereas the single disciplines are not mentioned. Table 2.10 shows the four cultural axes, also listing the competences for each of them. Each competence is in turn articulated in skills and knowledge.

Table 2.10: Italian base Competences at the end of compulsory education, authors elaboration from Cultural Axes, 1 in (MIUR, 2007)

CULTURAL AXIS	COMPETENCE	
Languages	Mastery in Italian language	Master the expressive and argumentative tools in order to manage oral interactive communication in different contexts
		Read, understand, and interpret different kinds of written texts
		Produce different kinds of texts related to different communication purposes
	Use a foreign language for the main communicational and operational purposes	
	Use the fundamental tools for a conscious appreciation for the artistic and literary heritage	
	Use and produce multimedia	
Mathematical	Use the techniques and procedures of the arithmetic and algebraic calculation, with their graphical representation	
	Compare and analyse geometric figures, identifying invariants and relationships	
	Identify the appropriate strategies for problem solving	
	Analyse and interpret data, developing deductions and reasoning on them also with graphical representations, consciously using calculation tools and features provided by specific computer applications	
Scientific and technological	Observe, describe, and analyse natural and artificial phenomena and acknowledge the various forms of the concepts of system and of complexity	
	Qualitatively and quantitatively analyse phenomena related to energy transformations starting from the experience	
	Be conscious of potentials and limitations of the technology in the cultural and social context of its application	
Social-Historical	Understand the change and the diversity of the historical times in a diachronic dimension through the comparison among historical periods and in a synchronic dimension through the comparison among geographical and cultural areas	
	Position personal experience in a system of rules based on the mutual recognition of the rights guaranteed by the Constitution, to protect person, community, and environment	
	Acknowledge the essential characteristics of the socio-economic system to orientate themselves in the productive framework of their own territory	

The Italian structure for competences also includes eight new competences, named citizenship key competences, to be achieved during the compulsory education. Offering the opportunity to clarify this quite complex situation, in (Zanchin, 2012) is proposed a comparison associating the four axes, languages, mathematical, scientific and technological, and social-historical, with the European and the Italian key competences. Table 2.11 shows that the citizenship competences are only partially included in the area of interest of the cultural axes. According to (Ronchetti, 2017), this is an evidence that the structure of the Italian solution derives from a “disciplinary approach”, as each cultural axis is a collection of different disciplines with homogeneous methods and languages. On the contrary, (Zanchin, 2012) suggests that the aggregation of disciplines into axes can help to promote a CBE approach.

Table 2.11: European key competences and Italian framework, authors elaboration on (Zanchin, 2012)

<table>
<tr><th>Recommendation of the European Parliament and of the Council – 18 December 2006</th><th colspan="4">Italian D.M. 139, 22 August 2007</th></tr>
<tr><th>Key competences for Lifelong Learning</th><th colspan="2">Cultural axes</th><th colspan="2">Citizenship key competences</th></tr>
<tr><td>Communication in the mother tongue</td><td colspan="2" rowspan="3">Languages</td><td colspan="2" rowspan="3">Communicate</td></tr>
<tr><td>Communication in foreign languages</td></tr>
<tr><td>Digital competence</td></tr>
<tr><td>Mathematical competence and basic competences in science and technology</td><td>Scientific and Technological</td><td>Mathematical</td><td colspan="2"></td></tr>
<tr><td>Social and civic competences</td><td colspan="2" rowspan="2">Social-Historical</td><td rowspan="2">Collaborating and participating</td><td rowspan="2">Acting autonomously and responsibly</td></tr>
<tr><td>Cultural awareness and expression</td></tr>
<tr><td rowspan="3">Learning to learn</td><td colspan="2" rowspan="3"></td><td colspan="2">Learning to learn</td></tr>
<tr><td colspan="2">Acquiring and interpreting information</td></tr>
<tr><td colspan="2">Finding links and relationships</td></tr>
<tr><td rowspan="2">Sense of initiative and entrepreneurship</td><td colspan="2" rowspan="2"></td><td colspan="2">Inventing and designing</td></tr>
<tr><td colspan="2">Problem solving</td></tr>
</table>

The Italian reform of the year 2010 acquired the reference to the CBE approach also for the upper secondary schools. With three decrees (*D.P.R. 15 marzo 2010 n. 87, 88 e 89*, 2010), the reform identified three different kinds of upper secondary schools: the schools of the most general education, called *Liceo*, the technical schools, and the vocational schools[11]. Each of the three different decrees of the reform law only details one kind of school, defining also the specialisations of that kind of school. For each kind of school the reform lists the learning outcomes of the general type, which students are expected to achieve at the end of the five years courses. The law defines 21 general learning outcomes for students of Licei, whereas the expected general learning outcomes are 22 for all the students of the technical schools. Furthermore, each of the different specialisations adds specific learning outcomes, which have been described as well. For example, besides the 22 general learning outcomes of the technical schools there are specific learning outcomes, 11 for the economic sector and 9 for the technological sector (see also Table 2.12).

11 Percentages of enrolled students for the school-year 2016/2017: 48\% for Licei, 31\% for technical schools, and 21\% for the vocational schools (see (“Portale unico dei dati della scuola,” 2017)).

Table 2.12: Number of learning outcomes in Italian technical schools and sectors

General learning outcomes	*Specific learning outcomes*	
For all technical schools	**Economical sector**	**Technological sector**
22	11	9

While no competence has been expressed for the Licei by the reform law, the two decrees related to the vocational and to the technical schools specify the learning outcomes in terms of competences. Focusing on the technical schools[12], a first set of competences for each of the two technical sectors specifies the learning outcomes for the general education area. The general education area includes the subjects which all the students of the sector have to study: Italian language and literature, English language, history, mathematics, law and economics, integrated sciences (earth science and biology), gym[13]. These subjects are the same for the two technical sectors, with the same number of hours of lessons during the five course years, and area called common disciplines (in Italian, *insegnamenti comuni*). The two sets of competences provided for the general education area of the economic and of the technological sectors differ for one competence, included only in the list of competences of the technological sector. The list with the 19 competences of the general education area for the technological sector is in Appendix A on page 105. As an example of how extensive these competence definitions are, we report here the definitions of four of these competences, adding for each of them the number corresponding to the list in Appendix A:

- Use the lexical and expressive heritage of the Italian language according to the communication needs of different contexts: social, cultural, scientific, economic, technological. (2)
- Acknowledge the value and the potential of works of art and environmental goods, to exploit and to enhance them adequately. (6)
- Use concepts and models of the experimental sciences to investigate social and natural phenomena and to interpret data. (12)
- Use networks and information technology tools as a support in the activities of study, research, and in-depth study. (13)

The reform shaped the two technical sectors, identifying different branches (in Italian, *indirizzi*). The economic sector includes two branches, whereas the technological sector includes nine branches. Most of the branches have been further divided into specialisations (*articolazioni*), as shown in Table 2.13 which also reports the number of competences which characterise the eleven branches of the Italian technical schools[14].

12 Many differences distinguish the technical schools from the Vocational schools, in Italy. Nevertheless, they compose what in European terms is called vocational education and training (V.E.T.). This is also confirmed by the decree n. 88, related to the technical schools (MIUR, 2007, p. 50).

13 Two tables contain the data, respectively for economic and technological sector, in (*D.P.R. 15 marzo 2010 n. 87, 88 e 89*, 2010, pp. 55 & 62).

14 The reform does not list the competences separately for the different specialisations, apart for the three specialisations of the Transport and Logistics branch, technological sector.

Table 2.13: Italian technical schools: sectors, branches, and specialisations

Sector name and no. of general education Competences	**Branch name and no. of Competences**		**Specialisation name**
Economical 18	Administration, Finance, and Marketing (AFM)	11	Base
			Business Information Systems (SIA)
			International Relations and Marketing (R.I.M.)
	Tourism	10	Base
Technological 19	Mechanics, Mechatronics, and Energy	11	Mechanics
			Mechatronics
			Energy
	Transport and Logistics	7	Construction of the vehicle
		8	Driving of the vehicle
		8	Logistics
	Electronic and Electrotechnics	7	Electronic
			Electrotechnics
			Automation
	Computer Science and Telecommunication	6	Computer Science
			Telecommunication
	Graphics and Communication	9	Base
	Chemistry, Materials and Biotechnology	7	Chemistry and Materials
			Environmental biotechnology
			Health biotechnology
	Fashion System	10	Textiles, clothing and fashion
			Footwear and fashion
	Agriculture, Agro-food and Agro-industry	8	Productions and transformations
			Management of the environment and the territory
			Viticulture and enology
	Buildings, Environment and Territory	8	Base
			Geotechnical

For all the 26 specializations of the 11 branches of the technical schools have been defined the subjects. For each subject the number of school hours has been planned per year.

Summarizing, the competences for the technical schools have been formally defined by the Italian educational institutions at three different levels:

(a) for disciplines of the general education;

(b) at the sector level;

(c) for the different branches.

No competence has been defined for the disciplines out of the group of the general education area. Even for the given competences, no detail on neither the contents nor the skills has been offered. Nevertheless, the law clarifies that a next set of guidelines will specify the learning outcomes in terms of competences, skills, and knowledge for the technical and for the vocational schools. Actually, less than two years later, the institutional framework became more complete when the Ministry for Education published the Guidelines implementing the new reform for the last three course years[15] of the technical (MIUR, 2012a) and of the vocational (MIUR, 2012b) schools. For the last three course years of the technical schools this measure points out the competences which articulate the learning objectives for each specific discipline.

The contents and the skills for each specific discipline have been defined, related to the second biennium and, separately, for the last year. For each subject, a list of contents and a list of skills are available for the second biennium, and another pair of lists of contents and skills are available for the last year, whereas a single list of competences is available for all the last three years. For example, the four competences provided for the mathematics teaching at the economic sector, i.e. last three course years, are associated with two lists of knowledge (contents) and two lists of skills. For the 3rd and 4th course years (2nd biennium) there are 16 knowledge and 14 skills descriptions respectively in the two lists, whereas for the 5th course year there are 8 knowledge and 8 skills descriptions. Table 2.14 synthesizes the situation with an extract of the contents and skills[16] stated for mathematics.

The numeric codes (10), (11), (13), and (15), added to the four competences for mathematics, link to the competences included in the list of the general education area competences of the economic sector. For other disciplines the competences list includes both competences of the sector and competences of the branch, as for the CS discipline described in subsection 2.3.

15 The Guidelines for the first two course years of the technical secondary schools have been published in 2010 (MIUR, 2010b), but further details on them would be out the scope of this thesis.

16 For each competence has been added the number corresponding to the Italian version of the competences for the general education area, contained in Appendix A, Competences in technical schools: area of general education.

Table 2.14: Last 3 years of Technical Economic sector: Competences, Contents, and Skills for Mathematics, authors elaboration on (MIUR, 2012a)

COURSE YEARS	**MATHEMATICS**		
	COMPETENCES	**KNOWLEDGE (CONTENTS)**	**SKILLS**
2^{nd} biennium	- use the language and the methods of Mathematics to adequately organise and evaluate qualitative and quantitative information (10) - use the strategies of the rational thinking in the dialectical and algorithmic aspects to deal with problematic situations, elaborating adequate solutions (11) - use networks and information technology tools as a support in the activities of study, research, and in-depth study (13) - correlate the general historical knowledge with the development of the sciences, technologies, and techniques, in the professional fields of specific reference (15)	Connectives and sentential logic. Variables and quantifiers. Hypothesis and thesis. The induction principle. The real numbers set. π number. Sine and cosine theorems. Addition and duplication formulas of the arcs. Circumference and parabola representation in the Cartesian plane.	Demonstrate a proposition from other propositions. Derive and apply formulas to sum the first n terms in arithmetic or geometric progression. Apply trigonometry to solve problems on triangles. Calculate limits of successions and functions. Analyse continuous and discontinuous functions. Calculate derivatives of functions. ......
5^{th} course year		Algorithms for approximating zeros of a function. Concepts of iterative and recursive algorithms. Problems and models of linear programming. Operational research and decision problems.	Solve and represent in a formalised way problems of both finance and economics. Use tools of mathematical analysis and of operational research in the study of economic phenomena and in the real business applications. Use the Bayes' rule in conditional probability problems. Select a simple random sample from a population. .....

Table 2.14 highlights that subject's competences are not directly linked to specific contents and skills, and the order of sequence in which the contents should be treated has not been defined. Schools and teachers are hence free to choose the timing for developing the defined contents. The institutional framework is going to abandon the prescription of a uniform working plan, and a fortiori of a national curriculum.

Summarizing, in Italian secondary school competences have been introduced by the reform as the leading approach for the upper secondary schools. Competences have been presented as guidelines, in which they are not strictly connected with the contents. These guidelines are not a national curriculum but rather a support for the schools' autonomy, a useful basis for developing their educational processes, as clarified in the document Premise in (MIUR, 2012a, p. 4). The approach is very different from that adopted in Austria, where "The freedom of planning lessons for three years with broad topics will be replaced by six semesters with preset learning objectives and self-contained modules" (Micheuz, 2016, p. 33). More autonomy for Italian schools and teachers means also more responsibility to realize the CBE approach through the everyday educational processes. The definition of the competences provided by the Ministry for all disciplines is detailed, but it is not prescriptive: teachers are free to follow the list of formal competences, or they can ignore the list, preferring a different solution and different definitions.

2.3 Competences of computer science in Italian secondary schools

The focus of this thesis is mainly on the technical schools, since they offer a meaningful range of competences in CS, also named Informatics, both in quality and in quantity terms (see Table 2.15 and Table 2.17). According to this characteristic, only for the technical schools Informatics is one of the subjects which can be included in the written test of the nation-wide final exam (in Italian, *Maturità*), directly prepared by the Ministry for Education. Both the economic and the technological sector of the technical schools have specialisations oriented to CS. The economic sector in the AFM (Administration, Finance, and Marketing) branch offers the specialisation called SIA (Business Information Systems, in Italian *Sistemi Informativi Aziendali*), whereas the technological sector in Computer Science and Telecommunication (*Informatica e Telecomunicazioni*) branch offers the two specialisations of Computer Science and of Telecommunication (respectively *Informatica* and *Telecomunicazioni*), however only the CS specialisation comprises the CS as a discipline of the final course year. The same CS specialisation includes other disciplines which are part of the disciplinary area of CS: Systems and Networks (*Sistemi e Reti*), Technologies and Design of Information and Telecommunication Systems (*Tecnologie e Progettazione di Sistemi Informatici e di Telecomunicazioni*). Even if the latter shares 4 out of 5 competences with the CS discipline, nevertheless we do not include these disciplines in our study because their topics represent mainly the networking part of the CS.

Table 2.15 gives the competences list of the CS discipline in the final triennium for the SIA specialization, AFM branch of the technical economic sector (MIUR, 2012a, p. 58). In the table, the numeric or alphanumeric code added to each competence links to a competence, included in a list: when the code is numeric, as for (13), (16), and (17), the competence has been extracted from the list of the general education area competences (Appendix A page 105); when the code is alphanumeric, as for BE3, BE4, BE6, BE7, BE8 and BE10, the competences has been extracted from the list of competences of the AFM branch of the economic sector (Appendix B).

Table 2.15: Last 3 years of Technical Economic sector, AFM branch, SIA specialisation: Competences for CS authors elaboration on (MIUR, 2012a)

	SIA specialisation: COMPUTER SCIENCE (INFORMATICS)
COURSE YEARS	**COMPETENCES**
2nd biennium	- use networks and information technology as a support in the activities of study, research, and in-depth study (13) - identify and apply methodologies and techniques of the project management (16) - edit technical reports and document individual and group activities, related to the professional environment (17) - interpret business systems through their models, processes, and information flows, related to different business types (BE3) - recognize different organizational business models, documenting the procedures and searching for effective solutions in stated situations (BE4) - manage business accounting system, using programmes for the integrated accounting
5th course year	

	system (BE6) - apply the principles and the tools of the programming and management control, analysing the results (BE7) - position the marketing activity into the business life-cycle and develop applications related to specific contexts and different market politics (BE8) - use business information systems and the tools of business integrated communication, in order to implement communication in different contexts (BE10)

The contents and the skills defined for the final triennium of CS discipline in the SIA specialization of the AFM branch of the technical economic sector have been collected in Table 2.16. Unlike competences, contents and skills are separately defined for the 2nd biennium, which includes the 3rd and 4th course years, and for the 5th course year.

Table 2.16: Last 3 years of Technical Economic sector, AFM branch, SIA specialisation: Contents and Skills for CS – authors elaboration on (MIUR, 2012a)

	SIA specialisation: COMPUTER SCIENCE (INFORMATICS)	
COURSE YEARS	**KNOWLEDGE (CONTENTS)**	**SKILLS**
2nd biennium	Programming languages. Software development methodology. Development phases of a software project. Information and automated information system in the business processes. Operative system: general aspect and evolution trend. Data Base Management System (DBMS). Database design. SQL language. Software supporting production and management of multimedia objects. Hypermedia design for the business communication. Languages and tools for web development. Structure, usability, and accessibility of a website. Computer and communication networks. Networking database. Business networking services. E-commerce. Social networking.	Describe resolving procedures through algorithms. Implement algorithms with different programming styles and suitable software tools. Produce project-related documentation, at the different phases. Design and implement databases according to the business needs. Identify innovative technology aspects to improve the business organization. Identify the telematic procedures supporting the business organization. Implement remote database with graphical interface on the web, according to the business needs. Design hypermedia supporting business communication. Design and implement static and dynamic web pages. Publish web pages on Internet. Evaluate, choose and adapt software application according to business characteristics and needs. Use the network potential for business needs.
5th course year	Cases of various difficulties focused on different company activities. Project development techniques for business process integration. Networking for business and public administration. Cybersecurity. Privacy and intellectual property protection, and cybercrime.	Identify and use software to support business processes. Collaborate in projects for integration of business processes (ERP). Publish web pages on Internet. Recognise the legal aspects connected to the use of computer networks, focusing on data security. Organise the communication on the networks to improve the flows of information. Use the Internet features and evaluate their evolution.

As shown in tables 2.15 and 2.16, whereas the competences describe the learning outcomes of all the final three course years, contents and skills are described with a list of 17 knowledge (contents) and a list of 12 skills, respectively, for the 3rd and 4th course years, also called 2nd biennium, and with a list of 5 knowledge and a list of 6 skills, for the 5th course year.

For the CS discipline at the technical technological sector Table 2.17 gives the competences list for the final triennium of the Computer Science specialization, CS and Telecommunication branch (MIUR, 2012a, p. 186). The code added to each competence corresponds to a competence included in a list. When the code is numeric, the reference is to the list of competences for general education area, in Appendix A. The alphanumeric code refers to the list of competences of the CS and Telecommunication branch of the technological sector, in Appendix B.

Table 2.17: Last 3 years of Technical Technological sector, CS and Telecommunication branch, CS specialisation: Competences for CS – authors elaboration on (MIUR, 2012a)

<table>
<tr><td></td><td>CS & Telecommunication specialisation: COMPUTER SCIENCE (INFORMATICS)</td></tr>
<tr><td>COURSE YEARS</td><td>COMPETENCES</td></tr>
<tr><td>2nd biennium</td><td rowspan="2">- use the strategies of the rational thinking in the dialectical and algorithmic aspects to deal with problematic situations, elaborating adequate solutions (11)
- develop computer applications for local networking or remote services (BIT6)
- choose devices and tools according to their functionalities (BIT1)
- manage projects according to procedures and standards, based on the quality and safety management system (BIT3)
- edit technical reports and document individual and group activities, related to the professional environment (17)</td></tr>
<tr><td>5th course year</td></tr>
</table>

The contents and the skills defined for the CS discipline in the final triennium for the CS specialization, CS and Telecommunication branch of the technological sector are shown in Table 2.18. As for the economic sector, contents and skills for the technological sector are separately defined for the 2nd biennium, which includes the 3rd and 4th course years, and for the 5th course year.

Table 2.18: Last 3 years of Technical Technological sector, CS and Telecommunication branch, CS specialisation: Contents and Skills for CS – authors elaboration on (MIUR, 2012a)

	CS & Telecommunication specialisation: COMPUTER SCIENCE (INFORMATICS)	
COURSE YEARS	**KNOWLEDGE (CONTENTS)**	**SKILLS**
2nd biennium	Fundamental relations among machines, problems, information, and languages. Languages and machines at different abstraction levels. Programming paradigms. Iteration and recursion. Fundamental data structures and their implementation. Text files. Theory of algorithmic complexity. Object-oriented programming. Event-driven programming and graphical interfaces. Software development tools and supports for programs robustness. Languages for web page definition. Client-side programming language for a local management of events in web pages. Dictionary of technical terminology, also in English language. National and European sector-specific regulation for safety.	Design and implement algorithms using various data structures. Analyse and compare different algorithms solving the same problem. Choose the most suitable data organisation to manage information in a given situation. Manage text files. Design and implement application according to the object-oriented paradigm. Design and realise user interfaces. Design, realise, and manage static web pages with local interaction. Use dictionary of technical terminology, also in English. Apply sector regulation for safety.
5th course year	Conceptual, logical, and physical model of a database. Languages and techniques for database query and manipulation. Languages for the server-side programming at application level. Techniques to realise dynamic web pages.	Design and realise computer applications accessing a database. Develop web-based applications integrating a database.

Chapter 3

Project-based learning

The CBE approach requires activating a learning process in which knowledge, skills, and abilities of the learners can be applied, developing their competences according to the principles of the theory of the constructivism, as described in 2.1.1.2. Such a learning process can be activated by inductive teaching methods, which set up “experiences that induce students to construct knowledge for themselves, when necessary adjusting or rejecting their prior beliefs and misconceptions in light of the evidence provided by the experiences” (Prince & Felder, 2006, p. 125).

This chapter deals with inductive teaching methods: inquiry learning, problem-based learning, case-based teaching, discovery learning, just-in-time teaching, and project-based learning. The first five inductive methods are described showing details and offering some example of practical implementation. A specific subsection gives more details on active learning, a feature present in all six inductive methods. The final section of the chapter describes the inductive method of the project-based learning (PBL), as long as the second research question of the thesis investigates the application of PBL.

3.1 Inductive teaching methods

In order to classify learning and teaching methods, a relevant distinction can be done between deductive and inductive methods, which are associated to different ways or visions of the learning process (Prince & Felder, 2006). According to the deductive method, teacher gives the lectures and pupils are required to applying what they are supposed to have learned. On the contrary, the inductive way pushes learners to build up their own pathway to learn, letting them discovering their learning process or, quoting McConnell (McConnell, 1996, p. 52), offering to learners their “journey of discovery” towards the learning. When learners face their knowledge needs in a not trivial situation proposed by teachers, then the individual learning need can become the strongest activator of the learning process. The inductive approach features methods with constructivist aspects of the learning.

Many inductive methods have been defined. The analysis in (Prince & Felder, 2006) points out the followings:

- Inquiry learning.

- Problem-based learning.
- Case-based teaching.
- Discovery learning.
- Just-in-time teaching.
- Project-based learning.

In the title of the article the two authors refer to these methods using both terms, *teaching* and *learning*, even though method names could suggest only partial descriptions, as some names refer to the teaching and others refer to the learning. According to the cited authors in the next subsections, which detail these six inductive methods, “we will never examine one *[e.g.: teaching]* without explicitly or implicitly considering the other *[e.g.: learning]*”, as Prince and Felder did in their article (Prince & Felder, 2006, p. 124).

3.1.1 Inquiry learning

The learning context of inquiry learning method is provided through questions, problems, or set of observations which students are required answering, solving, or explaining. Four types of inquiry have been identified in (Banchi & Bell, 2008), analysing scientific investigations at the elementary schools: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry.

Similarly the authors in (Cobern et al., 2014, p. 2270) “labelled as didactic direct, active direct, guided inquiry, and open inquiry” the categories of “instructional mode options” for science teaching at grades K-8.

The main characteristics of the inquiries types are collected in Table 3.1 where the short descriptions are derived by (Prince & Felder, 2006). The third column of the table, partially derived by (Alake-Tuenter, 2014), proposes a possible classification or grouping of the different inquiry types based on the different level of teacher intervention.

Table 3.1: Inquiry types and teachers/students regulation,
authors elaboration on (Prince & Felder, 2006) and on (Alake-Tuenter, 2014)

<table>
<tr><th>Inquiry type</th><th>Short description</th><th>Learning process management</th></tr>
<tr><td>confirmation inquiry</td><td>students are given a problem and a method, results are known in advance[17]</td><td rowspan="2">Teachers-regulated inquiry</td></tr>
<tr><td>structured inquiry</td><td>students are given a problem and an outline for how to solve it</td></tr>
<tr><td>guided inquiry</td><td>students must also figure out the solution method</td><td rowspan="2">Pupils-regulated inquiry</td></tr>
<tr><td>open inquiry</td><td>students must formulate the problem by themselves</td></tr>
</table>

The four types of inquiry are intended as the four steps in a process of improvement for students “toward deeper scientific thinking”, a progression that the Banchi and Bell call continuum: “The continuum focuses on how much information (e.g., guiding question, procedure, and expected results) is provided to students and how much guidance you will provide as the teacher” (Banchi & Bell, 2008, p. 26). As the concept of continuum reminds, identifying two management groups has

17 This is the only description derived by (Banchi & Bell, 2008). According to (Cobern et al., 2014), the confirmation inquiry should be defined active direct mode of instruction, where *direct* is used as opposed to the inquiry mode.

not to be intended as a rigid distinction but rather a general reference to build up an effective learning process, helping students to promote their learning awareness.

3.1.2 Problem-based learning

In the problem-based learning method the learning context provides the students an "open-ended, ill-structured, authentic (real-world) problem" (Prince & Felder, 2006, p. 128).

Role played by the teacher in this context is rather of facilitator than instructor, because students are required solving the problem mainly by their own, applying information and method acquired in advance. Nevertheless, based on the kind and scope of the problem, the problem-based learning method might include short interventions by the teachers, focusing on specific issues encountered by the class and requiring an additional learning support. Savery stresses that the teacher should not give any information to the pupils, acting as "a tutor who guides the learning process and conducts a thorough debriefing at the conclusion of the learning experience" (Savery, 2006, p. 12). Furthermore, he proposes a list of 10 essential characteristics required by the problem-based learning method. These characteristics "identify clearly:

1) the role of the tutor as a facilitator of learning,
2) the responsibilities of the learners to be self-directed and self-regulated in their learning, and
3) the essential elements in the design of ill-structured instructional problems as the driving force for inquiry." (Savery, 2006, p. 15).

The first point highlights the importance of a guidance, with the aim at supporting the learners in the reflection upon the learning experience, for example through a process of debriefing at the end of the experience.

As regard the second point, the author explains that the learning responsibility required to students could be a final goal rather than a precondition. To develop skills like problem solving, self-direct learning, and team-working, students not accustomed to problem-based method need an adequate instructional scaffolding.

According to the third point, the problem to be solved must engage the students in real world activities, and their engagement also helps in motivating the learning.

Besides these three points, we also observe that the problem-based learning method has been described as real collaboration demanding. According to Savery, collaboration seems to be required both by the teachers and by the students. For teachers, because the method depicts an integration process for the learning of a range of disciplines, while students need to share the information during the inquiry activities.

Finally, we note that the learners engaged in this method benefit widely by frequent feedback opportunities, offered by frequent assessment situations, required to deal with the problem. Savery suggests two different kinds of assessment:

- conducted by the learners, in the forms of self assessment and peer assessment;
- conducted by the teachers, measuring the learning progress of the students in term of knowledge and process as well, since the problem-based method requires learners improving the recognition of their learning progression.

Even though problem-based learning is frequently shortened as PBL, we will use the acronym for project-based learning, the method applied in the research conducted for this thesis.

3.1.3 Case-based teaching

Applying case-based method, teachers propose the students to develop the analysis of given situations, taken from the real world or realistic ones, called case studies. “A teaching case is a story, describing or based on actual events and circumstances, that is told with a definite teaching purpose in mind and that rewards careful study and analysis” (Lynn, 1999, p. 2). A case is supposed to stimulate the students in developing the problem solving and making decisions skills. To this aim, cases should be discussed in class.

In the field of engineering, according to Kardos, “One of the best ways to enhance learning with Engineering Cases is by means of classroom discussion.” (Kardos, 1979). Based on the context elements, as for example the teacher, the class, and the case itself, the discussion could also proceed freely. However, the discussion progresses usually follow a structure which has been called “systematic discussion”, articulated in the following steps:

“(1) Review of the case content

(2) Statement of the problems

(3) Collection of the relevant information

(4) Development of alternatives

(5) Evaluation of alternatives

(6) Selection of a course of action

(7) Scheduling of recommended solutions.” (Kardos, 1979)

Not all the forms or applications of the case-based teaching method are inductive. For example, “research cases” can be used by teachers to “illustrate appropriate, typical, or exemplary decision making”, with details on the adopted solutions and the obtained results. Showing all the steps of a research case to the students can help them to know the solutions provided and the decisions taken by experts or professionals. This form of case-based teaching method is not a context adequate to stimulate the problem solving and making decision skills. As a consequence, “research cases” can not be included among the inductive methods (Lynn, 1999).

On the contrary, in “teaching cases” it is clear that “the circumstances of the case are described but the decisions made by the protagonists are withheld so that the students can do their own analysis and decision making” (Prince & Felder, 2006, p. 132). The same authors claim that the case-based method and the problem-based method share many characteristics. At the same time they also highlight some differences, which are collected in Table 3.2. We add the project-based learning method as well (see section 3.2), in order to enrich the comparison.

Table 3.2: Differences among three inductive methods, authors elaboration on (Prince & Felder, 2006)

Method	***Problem's structure***	***Details on the context***	***Material and knowledge***
case-based	relatively well-structured	rich details are provided	apply material already somewhat familiar
problem-based	poorly structured	not many details	acquisition of new content knowledge
project-based			apply known material and acquire new one

3.1.4 Discovery learning

Discovery learning is a method which adopts the characteristics of the inquiry learning, particularly emphasising that the students deal with their tasks in a self-directed manner, also discovering the conceptual knowledge during the work (Prince & Felder, 2006). This method could sound too demanding, as it requires students "to discover everything by themselves". Nevertheless a less extreme variant of the method, called the "guided discovery", allows teachers supporting the learning process. This variant is hardly distinguishable by the guided inquiry (see Table 3.1 in subsection 3.1.1).

3.1.5 Just-in-time teaching

Just-in-time teaching method, also abbreviated as JiTT, can be developed through three steps which in different ways engage students and teachers:

- the students receive an assignment, often called warm-up, which requires working on at homework on a topic not yet studied at school;
- the teacher receives and analyses the students' answers to the assignment;
- students and teacher discuss on the topic of the assignment.

Aspects of this method worthy to be detailed are:

a) "Information-gathering activities are assigned *before* a topic is seen in class" (Lasry, Dugdale, & Charles, 2014, p. 34). As a consequence, the first impact of the students with the topic "happens *before* any formal classroom instruction" (Novak, 2011, p. 64), not in a traditional instruction context.

b) The preliminary homework includes a couple of questions that students have to answer to.

The forms and the kinds of the assigned activities might vary, but the students' work has always to be reviewed by the teacher before the class, in order to collect the first feedback. Based on this feedback, the teacher "adjust the lessons accordingly" (Prince & Felder, 2006). As this could be done shortly before the class, in a very short time, the method has been called *just-in-time*.

The JiTT method has been initially introduced as a “Web-based pedagogy, but [...] All JiTT instruction occurs in a classroom with human teachers. The Web materials [...] act as a communication and organizing tool. [...] JiTT practitioners view their pedagogical strategy as feedback loops between teaching and learning and between in-class and out-of-class experiences” (Novak, 2011, p. 65).

Besides the frequent feedback, the JiTT method promotes the learning from mistakes approach. To this aim, teachers are required to “show interest in the useful mistakes students make and offer corrective support” (Novak, 2011, p. 66). As mistakes are part of the learning process, students have to be encouraged to deal with the assigned tasks, producing also various attempts but without severe punishment neither bad marks in case of mistakes. For the same reason, the progress in the learning of the students has to be supported all along the process. “Teachers and students become a teaching-learning team” (Novak, 2011, p. 64).

Summarizing the aspects distinguishing JiTT from traditional methods, we highlight with Table 3.3 the different roles and actions expected by teachers and by students in JiTT: the students start to learn element of the treated topic; the teacher knows the level of the students for the topic, before the class; the students have to play a role as responsible for a part of their own learning.

Table 3.3: Students and Teachers actions in JiTT, authors elaboration on (Novak, 2011)

The students	The teachers
Attend the lesson with a good start into the learning process of the treated topic. Have to play a role as responsible for a part of their own learning.	Lecturer knows the level of the students for the topic, before the class.

As a specific application of the JiTT we mention the flipped classroom method, which has become quite popular in recent years. The flipped classroom method provides two out of the three relevant aspects of JiTT, because the “students gain first exposure learning prior to class and focus on the processing part of learning (synthesizing, analyzing, problem-solving, etc.) in class.” (Brame, 2013). The teacher’s role is a little different. In the flipped classroom apparently the teacher is able to know the level reached by the students only during the lessons, and not before the class like in JiTT.

Different kinds or variants of flipped classroom have been applied, according to (Brame, 2013). For example the “inverted classroom” provides the students with various kinds of materials, related to the topic to deal with, before the class. In this way, the students have their first exposure in a place and time which are not school. In order to support the preparation of the students, they are also required filling the worksheets, which the teachers randomly collect and review. In this case the first feedback is less strict than in JiTT. Then, the work continues at school, were the students are encouraged to apply the acquired knowledge in different activities.

Another variant of the flipped classroom is the “peer instruction” (PI). In this case, the first exposition of the students to new topics includes the assignment of quizzes, which brings a bigger number of learners to be prepared for the class. Furthermore, the class activities require all students being active: all of them must give their answer to the questions posed by the teacher, and electronic solutions might allow the learners to remain anonymous. Whatever the variant adopted, according to (Brame, 2013) there are four key elements of the flipped classroom, which are included in Table 3.4.

Table 3.4: The flipped classroom with 4 key elements, authors elaboration on (Brame, 2013)

Key element	**Notes**
Provide an opportunity for students to gain first exposure prior to class	The pre-class exposure could be either high-tech or not
Provide an incentive for students to prepare for class	Mark the learners' work with points, "the common language of" the students
Provide a mechanism to assess student understanding	Much feedback and informal checks come from the class activities
Provide in-class activities that focus on higher level cognitive activities	As the basic knowledge is not gained at school, class time support deeper learning

3.1.6 A common feature of inductive teaching methods: active learning

Prince and Felder (Prince & Felder, 2006) observe that the six inductive methods share nine characteristics or features at various and different levels. These features describe three relevant aspects:

Learning context. The context for learning can be provided by:

- questions or problems;
- real-world problems;
- major projects;
- case studies.

Learner role. The involvement of the learner in the learning process with a the role for:

- discovering the content for themselves;
- partially anticipating the learning difficulties (a kind of flipped-classroom);
- self-directed learning;
- active learning.

Team-based learning. The adoption of the team-based learning, in the form of:

- collaborative/cooperative learning.

The shared features can be offered in different solutions by the various implementations of each method. According to the analysis in (Prince & Felder, 2006), the only feature always presents in all the six methods is the active learning. As a consequence, active learning can be considered the hallmark of the inductive approach.

The term "active learning" can easily recall its counterpart, the "passive learning". In both cases, we use the term to highlight the level of participation to the learning process and awareness of it by the major player: the learner. Using the term "active", we refer to an attitude of the learner towards the transformation process called learning, with the aim at understanding whether the learner is an active part of the process or not. An active learner must be aware of his/her learning process, and could also become responsible for his/her learning. Active learning emerged as a feature to contrast the risk of a passive attitude of learners towards the learning process, resulting from a traditional way of teaching committed to providing direct instruction. Active learning is part of an evolution which changes the point of view on the education, moving from teacher position towards learner position, with more attention for the learning process.

Nevertheless, “simply adopting” an inductive method does not guarantee good results. One reason is that “many students are resistant to any type of instruction that makes them more responsible for their own learning, and if the appropriate amount of guidance and support is not provided when inductive methods are used, the resistance can escalate to hostility, inferior learning outcomes, poor evaluations, and a resolution by the instructor never to try anything like that again” (Prince & Felder, 2006, p. 135).

Active learning has been suggested as an effective way to improve the achievement of the learning outcomes, in crucial subject areas (Freeman et al., 2014) and many studies confirm that good results can be reached. Nevertheless, in order to focus on core educational methods analysed in this thesis, we need to highlight at least some basic fundamentals; among these, reflection, responsibility, and group-work are included.

We start citing a relevant text book, used worldwide by perspective computer science teachers, and in related training courses. In the “Guide to teaching Computer Science. An activity-based approach.” (Hazzan, Lapidot, & Ragonis, 2011), the rationale underpinning the book is the active learning, clearly suggesting its adoption in computer science teaching. This textbook does not analyse the active learning in details, even tough it includes references to the literature on the field. Among others, the book cites (Newman, Daniels, & Faulkner, 2003) to highlight the relationship, proper of the constructivism, between the learner and the learning materials, in order to “encourage learners to be active in their relationship with the material to be learned” (Newman et al., 2003). As observed in (McConnell, 1996), “the idea is to get students thinking about the material” (ibidem, p. 52) of study. Other authors underline the responsibility of the learner during the learning process (Blumenfeld et al., 1991).

One of the recurrent aspects emerging from implementations of active learning is the group-work, obtained by grouping students and forming learning teams. A connected issue is the assessment of the students working in groups. For the active learning exercise analysed in (Hazzan & Dubinsky, 2010), a grading scheme has been suggested. Also in this case, a specific attention has been given to various individual aspects, connected to active learning.

Other works highlight that some actions can be classified as active learning activities, even though they are not played in groups. For example, (Shang, Shi, & Chen, 2001) define that the two components involved in the active learning approach are the experience and the dialogue. Experience can be done by observing or by doing, whereas dialogue can be with self, also called reflection, or be dialogue with others. Accordingly, the authors derive four modes of learning, which are summarized in Table 3.5. Each of four empty cells on the intersections of rows and columns represents the multiple solutions of a given mode of learning, obtained combining in various ways the components of dialogue and experience.

Table 3.5: Learning modes: combine experience and dialogue, authors elaboration on (Shang et al., 2001)

<table>
<tr><td></td><td></td><td colspan="2">Dialogue</td></tr>
<tr><td></td><td></td><td>With self</td><td>With others</td></tr>
<tr><td rowspan="2">Experience</td><td>Observing</td><td></td><td></td></tr>
<tr><td>Doing</td><td></td><td></td></tr>
</table>

The authors suggest as well to use the four different modes alternating them in teaching, with the aim at enriching the learning process.

3.2 Project-based learning: main principles

Prince and Felder provide the following definition of project-based learning method: “PBL begins with an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model, a device or a computer simulation” (Prince & Felder, 2006, p. 130). The learning activities require learners contributing in order to obtain a final outcome, which is a real product. Whether or not a physical object, the final product is the goal for the students during the project period. Even though the product is apparently the main result to construct, the relevant learning outcome for the students is to become responsible and autonomous in constructing their own learning.

The name of the project-based learning is shortened as PBL in this thesis, even though using the acronym for problem-based learning is also common. Table 3.6 shows the similarities and the differences between the problem-based and the project-based methods, described in (Prince & Felder, 2006, p. 130). The authors highlight that “In practice [...] the distinction between the two methods is not necessarily that clean”.

Table 3.6: PBL and problem-based learning: similarities and differences, authors elaboration on (Prince & Felder, 2006)

Similarities				
- normally involve teams of students - in open ended assignments - assignments resemble challenges encountered as professionals - call for the students to formulate solution strategies and to continually re-evaluate their approach in response to outcomes of their efforts				
Differences				
	Scope	*Central focus of the assignment*	*Required knowledge*	*Emphasis on*
Problem-based	narrower	the solution may be less important	acquisition of new knowledge	acquiring knowledge
Project-based	broader; may encompass several problems	the end product	application of previously acquired knowledge	applying or integrating knowledge

Besides Prince and Felder, another definition taken from a literature review regarding the effectiveness of the method could be cited here: “Project-based learning can be described as student-centred instruction that occurs over an extended time period, during which students select, plan, investigate and produce a product, presentation or performance that answers a real-world question or responds to an authentic challenge” (Holm, 2011, p. 1).

Both definitions include a key component of PBL: students are directly engaged to produce something. Holm’s definition, adding some more details, can help to identify additional elements:

- The production required to the students must be realistic, i.e. “answers a real-world question or responds to an authentic challenge”.

– The kind of product to realise can quite widely vary, including also outcomes which are less material as “presentation or performance”, besides “a design, a model, a device or a computer simulation”.
– The learning activity has to be not trivial. As a consequence, the project must require a meaningful time or, as said, “occurs over an extended time period”.
– The students can be involved in the different phases of the project, when they variously participate to “select, plan, investigate and produce” the final result.

The Holm’s definition adopts a wider meaning of PBL, partially including the problem-based learning method, further confirming in this way how difficult it is to get a sharp distinction between different methods.

More classifications and principles emerge reviewing the origin of the PBL method, often traced back to William H. Kilpatrick, also called “Mr. Project Method”. The Knoll’s reconstruction about the evolution of the project as a method of institutionalised instruction has shown that Kilpatrick could be consider “not the classic of the project method, but rather the classical outsider” (Knoll, 2012, p. 1), and that the first application of projects to education was in Europe, around two hundreds years before Kilpatrick article.

In the late 16th century the Italian art academy Accademia di San Luca in Rome was used to give the best students a challenging assignment, in a kind of competition which became an ordinary activity only in 1702 (Knoll, 1997, p. 2). According to Knoll, the Prix d’Emulation introduced by the Académie Royale d'Architecture of Paris in 1763 is the further evolution of the initial idea of competition, and can be taken as the first example of a learning method based on project.

Nevertheless, the contribution of Kilpatrick to the development of PBL remains relevant, under different points of view. For example, in order to support the opinion that the education has to be part of the life and not merely be a preparation for later living, Kilpatrick developed the principle of the “purposeful act”, the free and deliberate acting of a person in a democratic society. Since “the purposeful act is the typical unit of the worthy life [...]” then “To base education on purposeful acts is exactly to identify the process of education with worthy living itself” (Kilpatrick, 1918, p. 6). As a consequence, pupils have to feel that the activities developed during the learning process are consequence of their purposeful acting: “Kilpatrick established student motivation as the crucial feature of the project method” (Knoll, 1997, p. 5).

The list of the different types of project is “as wide as the purposes in the life”. For this reason, we suggest in Table 3.7 the classification originally proposed in (Kilpatrick, 1918, p. 16).

Table 3.7: A classification of different projects types, authors elaboration on (Kilpatrick, 1918, pp. 16–17)

Type	The purpose is to	Notes or examples	Steps
1	Embody some idea or plan in external form	Building a boat	Purposing, planning, executing, judging
2	Enjoy some (esthetic) experience	Listen to a story, hearing a symphony	- - -
3	Straighten out some intellectual difficulty, to solve some problems	To find out whether or not the dew falls	(See Dewey & McMurry)
4	Obtain some item or degree of skill or knowledge	Learning the irregular verbs in French	*same as type 1*

Projects of type 1 include four steps that, in an ideal application of the method, have to be taken by pupils. However the teacher must steer the process, in order to avoid the two "opposed dangers […] on the one hand that the child may not come out master of the process, on the other, that he may waste time" (Kilpatrick, 1918, p. 17).

As highlighted by Kilpatrick, type 2 of aesthetic experience has been included in the list of project types only because the purpose factor guides the learning process.

Type 3 refers to the problem type defined by Dewey, who discusses manual training, arguing that it "may also be used for presenting typical problems to be solved by personal reflection and experimentation, and by acquiring definite bodies of knowledge leading later to more specialized scientific knowledge" (Dewey, 1910, p. 168). Later on he concludes that, when suitably planned, "intelligent consecutive work […] will inevitably result in students not only amassing information of practical and scientific importance in botany, zoology, chemistry, physics, and other sciences, but (what is more significant) in their becoming versed in methods of experimental inquiry and proof" (Dewey, 1910, p. 169).

Type 4 might seem similar to type 1, including also the "two dangers" cited above. The planning step in the learning process of type 4 should be done by an expert in the field. Kilpatrick offers a relevant conclusion explaining the twofold meaning of the term *efficiency*, related to the project method. According to the author, when the project method has a proper application it is *efficient* both in achieving the project goal, for example the product to obtain by the activity, and in "securing the learning" which that activity potentially contains.

Further characteristics of the PBL method are collected in another literature review on PBL (Thomas, 2000). The author introduces PBL as a "model that organizes learning around projects". Then he offers five criteria to understand "what must a project have in order to be considered an instance of PBL" (Thomas, 2000, p. 3). The five criteria are:

Centrality. PBL projects are central to the curriculum, because "students encounter and learn the central concepts of the discipline via the project", which is not an enrichment project".

Driving question. Students involved in PBL projects deal with central concepts and principles of a discipline, because projects focus on questions driving towards that concepts and principles.

Constructive investigation. PBL projects must involve students as main actors, aware of the ongoing transformation and construction of their own knowledge, in terms of new understandings and new skills. This point has been underline as well in (Krajcik & Blumenfeld, 2006, p. 318), when authors say that PBL "is based on the constructivist finding that students gain a deeper understanding of material when they actively construct their understanding by working with and using ideas".

Autonomy. "PBL projects are student-driven to some significant degree" and "incorporate a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects".

Realism. PBL projects "embody characteristics that give them a feeling of authenticity to students".

Aalborg University in Denmark offers a meaningful example of institution founded on the pedagogic premise of PBL. According to (Dym, Agogino, Frey, & Leifer, 2005), project-organized education at Aalborg University proposes to integrate two different kinds of project-organized education, detailed in Table 3.8: design-oriented and problem-oriented education. Aalborg

University applies design-oriented, largely in undergraduate programs, and problem-oriented, mostly in graduate programs.

Table 3.8: Two kinds of project-organised education, authors elaboration on (Dym et al., 2005, p. 110)

Project-organized education kind	Deals with	Description
Design-oriented	Know how	The practical problems of constructing and designing on the basis of a synthesis of knowledge from many disciplines
Problem-oriented	Know why	The solution of theoretical problems through the use of any relevant knowledge, whatever discipline the knowledge derives from

Different types of projects might require different degrees of student autonomy. According to (Graaff & Kolmos, 2003), three main kinds of project work can be distinguished: task project, discipline project, and problem project. Table 3.9 shows the three kinds and a short definition of them.

Table 3.9: Students' autonomy in PBL: three kinds of project, authors elaboration on (Graaff & Kolmos, 2003)

Task project	Student teams work on projects defined by the instructor, using largely instructor prescribed methods. Minimal student motivation and skill development: students must complete the project according to provided guidelines.
Discipline project	The instructor defines the subject area of the projects and specifies in general terms the approaches to be used (which normally involve methods common in the discipline of the subject area), but the students identify the specific project and design the particular approach they will take to complete it.
Problem project	The students have nearly complete autonomy to choose their project and their approach to it

Many aspects of the PBL method have been discussed in literature and teachers have to keep them in mind. Teachers introducing PBL are as well “changing the culture of the classroom from the transmission-and-acquisition style that students expect” (Krajcik & Blumenfeld, 2006, p. 325), and might not be easy to obtain. PBL is a method which can develop competence, according to research (Blumenfeld et al., 1991, p. 380), and this is the starting assumption for the studies designed and realised for the phd project and thesis.

Chapter 4

The research

Many researchers and institutions in the field of education are striving to align the different levels of the education system to the growing needs and requirements of society. As summarized in sections 2.1.4 and 2.2, a meaningful part of these attempts have been concentrated on a systematic introduction of the CBE approach into education systems. Nevertheless, an institutional reform pushing the CBE approach could be not enough to achieve an adequate paradigm change in education. This situation has been synthesised by the author of a book, meaningfully titled "From Policy to Practice: How Competency-Based Education Is Evolving in New Hampshire", who claims "that competency-based education is not merely a policy shift, but also requires the hard work of designing a wholly new teaching and learning model on the ground" (Freeland, 2014, p. 21). Incorporating the CBE approach into daily activities of an education system with an effective and operational support is a hard job to carry out.

This thesis suggests a possible contribution to this objective. The purpose of the phd research was to identify and to investigate solutions to support the adoption of the CBE approach for teachers in Italian secondary schools, as this approach has been formally introduced by educational institutions but it is not yet a common practice in classes.

The chapter describes the research problem and declares the purpose statement on which we defined the two research questions that are the basis of the thesis.

4.1 The research problem and the purpose statement

The aim of this section is to introduce our research problem: Italian secondary schools have adopted the CBE approach in a limited way.

When we started to investigate the situation in secondary schools in Italy, in order to understand if the CBE approach is adopted by secondary school teachers, we focused on the province of Trento, in the North of Italy. Two sources supported our research.

Firstly, the inquiry of a project called eSchooling, pushed through by a Provincial Law in Trentino (a province in the north of Italy) on incentives for businesses, provided us with the opportunity to look into teaching methodology and related issues. That project, which was co-funded by the local government, the Autonomous Province of Trento (PAT)[18], involved various

18 Italian acronym for Provincia Autonoma di Trento

different companies: Telecom Italy SpA[19], the publisher Edizioni Centro Studi Erickson SpA[20], and two SMEs Memetic Srl[21] and ForTeam Studio Srl[22]. The University of Trento participated as an advisor. The specific goal of the project was the development of an ICT-based framework, to support teachers in the adoption of a competence based teaching approach (Chiozzi, Giaffredo, & Ronchetti, 2015). For this reason the eSchooling project included various research activities, such as meetings, workshops, interviews, and surveys, which involved approximately 120 teachers in two workshops, and 300 teachers in a survey. Opinions and data collected from teachers have been used in this phd work to support our idea of a research project.

Secondly, through an initiative called "Conversation on the Competence-based approach to Education" we interviewed CS teachers to observe how accustomed they are to using the CBE approach and related terms (Giaffredo, Mich, & Ronchetti, 2017). Three materials were used for the interviews: a plan for conversations (Appendix C), an information sheet with informed consent form (Appendix D), and a conversation guide sheet (Appendix E). The conversation guide sheet was designed as a basis for our semi-structured interviews.

The first interview was conducted with the sole purpose of testing and fine-tuning the guide sheet. Each interview lasted more than one hour and the interviews were audio recorded with the interviewer taking notes. These notes have been reviewed and checked with the audio tracks. No transcription of the recordings was made. The focus of our interviews was on subject-specific competences, also named discipline-specific competences. In 2016, in the Province of Trento there were more than 60 CS teachers. Licei and vocational schools have not been included in the sample because they do not have a written test for CS in the final exam (in Italian, *Maturità*). The interviews were planned to comprise technical schools offering CS subject in different locations within the province, and to include different kinds of CS teachers. We interviewed a sample of eight people, more than 10% of the whole population of CS teachers. Three out of the eight interviewees were technical-practical teachers (in Italian *insegnante tecnico-pratico*, ITP). Only one teacher had not taught in 9th-10th grade classes over the last three school-years. The 10th grade is of considerable importance because students who successfully complete it attain a competence certificate (see section 2.1.6), alongside the regular school report, both compiled by all the subject teachers on the student's course year. The regular school report shows marks for the students' knowledge pertaining to the disciplines. According to four interviewees, the competence certificates were filled in only after a group discussion regarding the marks included in the school report.

The results collected both from the eSchooling project and through interviews of "Conversation on the Competence-based approach to Education" helped us to define our research problem, stated at the beginning of this section and recalled here: in spite of the formal definition of the set of competences given by the Ministry of Education, classes in Italian secondary schools adopt the competence-based teaching approach only in a limited way.

Our purpose statement can be defined now: the research aims to identify solutions to support the adoption of the CBE approach for teachers in Italian secondary schools.

4.2 The research questions

The session defines the research questions of the thesis.

First research question:

19 the largest Italian telecom operator: www.telecomitalia.it

20 www.erickson.it

21 www.memetic.it

22 www.forteam.it

Are CS secondary school teachers encouraged to adopt the CBE approach when they are involved in the definition of the set of competences?

Second research question:

Are CS secondary school teachers induced to adopt the CBE approach when they are applying the PBL method?

Our research aims to discover solutions able to support the adoption of the CBE approach for teachers in Italian secondary schools. As the research relates to the field of CS, we focused on CS teachers. Accordingly, we identified possible solutions that we considered worth analysing by means of experiments with Italian CS secondary teachers in technical schools.

As claimed in (Freeland, 2014, p. 21), the formal definitions stated by educational institutions do not help the design of a "teaching and learning model on the ground". Consequently, we investigated the current situation among the teachers.

Firstly, in a meeting of the eSchooling project we met around sixty teachers of different disciplines, through a focus-groups activity.

Secondly, we interviewed CS secondary school teachers through the initiative "Conversation on the Competence-based approach to Education".

The collected data describe a process of adopting the CBE approach in class that is not complete. Teachers of focus groups described the "lack" or "fuzziness of the guidelines" to the adoption of the competence-based approach, "declaring also a low level of trust on the competence proponents" (Giaffredo, Mich, & Ronchetti, 2015). Data from interviews also suggest that "the institutional framework of the competences […] was scarcely used as a practical reference for teaching activities" (Giaffredo et al., 2017). Teachers are teaching professionals, then their role takes place mainly in the classroom. On the one hand teachers usually do not participate in defining which competences their students should attain. On the other hand, the formal definition of the set of competences issued by the Ministry for education does not make their use in the class compulsory. As a result, some teachers do not adopt the CBE approach at all, whereas other teachers prefer to adapt formal didactic concepts to their own concepts of competences, which often are not shared with colleagues. The first research question originates from this situation. What may be the impact of involving teachers in defining competences? Could they be encouraged to adopt the CBE approach if they were more involved in the decision-making process?

Subsequently we analysed many educational methods, particularly the inductive methods which specifically focus on skills development, a relevant component of all competences. Our goal was to investigate a teaching method able to induce teachers to adopt a CBE approach. The candidate method was required to:

- support the adoption of the competence based approach;
- be a common or popular method for CS teachers, some of whom involved in the research.

During the previously mentioned initiative "Conversation on the Competence-based approach to Education", all interviewed CS secondary school teachers claimed to use student projects in their classes because students are directly involved in the educational process: they are more interested in the class work and more active in the learning process. For these reasons, teachers think that student project is a suitable method to directly involve students in the educational process. Student projects share relevant aspects of the PBL method, even though they are not fully PBL activities.

Consequently, we focused our study on the PBL method. Focusing on Italian secondary school, the second research question directs us to look at the impact that the application of the PBL method in classes has on the adoption of the CBE approach, in order to understand if the PBL method can have positive effects on adoption of CBE approach by CS teachers.

4.3 The research methods

In order to answer the research questions as effectively as possible, this work has been divided into two parts corresponding to the two research questions: Teachers participate in the competences definition (Chapter 5) and Applying project-based learning method and adopting competence-based approach to education (Chapter 6). This section describes a synthesis of the research methods used for the two parts.

Considering the first research question, we needed to understand if involvement of CS secondary school teachers in the decision-making process of competence definition is effective in convincing those same teachers to adopt the CBE approach. To this goal we designed a system to enable the customisation of the description of competences. This system allows teachers to provide their own definitions of CS competences. The software implementing the system has been designed and developed as described in section 5.3 and this software system should provide functionalities enabling teacher interaction in defining competences. After delivering the system to a sample group of teachers, those same teachers were observed. This observation enabled us to investigate if participation in the process of competence definition effectively encourages teachers to adopt a CBE approach in the class. At the end of the experiment, a final questionnaire was submitted to teachers.

Considering the second research question, in order to understand if supporting PBL method can prompt teachers to adopt the CBE approach, we realised two studies observing ongoing student project activities, and applying two methods in two defined contexts. The first research method consisted of an action research course, whereas the second research method was a collective case study.

The action research training course on the PBL was provided to CS secondary school teachers. This kind of course aims to motivate the participants, teachers in this case, in their direct action in classes, alternating the instruction part of the course and the operative activity in the classroom with students. In this way, the teachers receive an incentive to rapidly put into practice and turn into a practical activity the main notions suggested during the instructional part of the course. As a consequence, the parallel development of theoretical and practical activities supports teachers in their reflection on the PBL method, core of the course. A questionnaire on the PBL and the CBE approach, submitted at the beginning and at the end of the course, was designed to pick up on possible and hoped-for changes in attendees. During the course, attendees accessed a software platform supporting PBL activities in a CBE framework.

The collective case study had the goal to observe some student project activities, managed by teachers with their pupils, in two technical schools of secondary level. Ten teachers proposed in six classes different student projects. Running these projects, students performed a variety of tasks to create the required product or artefact, driven by their teachers through the project phases. Observed teachers accessed the same platform used in the action research course.

4.4 The research plan

The research plan reflects the characteristics of the research. Activities planned to address the two research questions are described in this section.

The following activities address the first research question, managing the software system which aims to elicit interactive participation in a decision-making process, namely the definition of the set of competences:

1) Design and development of the system cover no more than a three-months period.
2) The final test of the software system was planned for January 2016, whereas system delivery to the sample group of teachers was scheduled for the following spring.
3) The final questionnaire had to be submitted before the summertime.

The following activities address the first study of the second research question, managing the action research training course for CS teachers:

4) The course had to take place over the 2015/2016 school-year.
5) The first and last dates of the course had to be the submission dates of the same questionnaire, whereas the direct observation of PBL activities in the classroom had to be directly planned with the teachers.

The following activities address the second study of the second research question, managing the collective case study:

6) The student projects had to take place over the 2016/2017 school-year.
7) The collective case study had to start with ice-breaking interviews, followed by directly observing teachers doing PBL activities.
8) According to teachers' requirements, support for specific techniques of PBL method had to be provided.

Chapter 5

Teachers participate in the competences definition

This chapter describes the work done in order to answer the first research question:

> *Are CS secondary school teachers encouraged to adopt the CBE approach when they are involved in the definition of the set of competences?*

Considering this research question we worked to understand if the CS secondary school teachers are pushed to adopt the CBE approach when involved in the definition of the set of competences for their discipline. The official or formal definitions of competences described by the CBE state of art in Chapter 2 are given by educational authorities, both institutions and research groups, leaving limited options for customisation by teachers. If teachers could adapt and customise the definition of the competences, would they be more interested in adopting the CBE approach, as competence definitions partially include their opinions? In order to answer this question, we planned and designed a system to support the customisation of the CS competences definition. Such customised definitions should fit the educational requirements of CS discipline, according to the opinion of the teachers.

This chapter describes the design and the final version of a software system, created as a teacher support system for a participated definition of the set of competences. The name of the software system is CoMak, which stands for Competence Maker. The chapter describes the purpose of CoMak, some aspects of its development process, and the system features.

5.1 Design of a participated definition process

Besides the set of competences defined by educational institutions, we assumed that a definition process involving teachers could help them to adopt the CBE approach. Furthermore, teachers should share the competence definition process, as different disciplines and teachers participate in developing both general competences (see section 2.1.3) and general education area competences as well as branch specific competences (see Table 2.15 in section 2.3).

A participated process gives teachers the opportunity to propose, discuss, and finally define competences. The software system supporting this participated process should offer services for a collaborative definition of the set of competences. Teachers accessing the system are enabled to view all the competences collected by the system. The competences are related to different types of schools, with their different sectors, branches, and specialisation, conforming to the organisation and structure of Italian secondary school, described in section 2.2 and synthesised in Table 2.13. System users are also enabled to take part in the social definition of competences, the most relevant feature which implements a “miniforum” on competences. As the participated process requires distributing the roles among teachers, users of miniforum can play different roles: submit a proposal for a new competence; moderate the discussion around a proposal; add a comment about a proposal. All users might submit a proposal, participate in the discussion on a proposal, and be a moderator. The only limit is that a proposer can not be a moderator of her or his proposal. This participated process could activate a discussion, resulting into a rejection, when the proposal has not been accepted by the moderator, or into an approval. In the latter case, the proposal becomes a competence.

Miniforum is the CoMak functionality for managing the participated decision. Miniforum offers teachers the opportunity to collaborate in order to define the competences which fit their ideas on the discipline. Nevertheless, teachers also maintain a reference to institutional competences. For this reason, the system should host both institutional and social-defined competences.

5.2 The research method

We decided to develop a software system to support the process of a participated definition of the set of competences. Considering that the constructivism is the basis of the CBE approach, we would highlight that the software system should be a “competence maker”. Accordingly, we called it CoMak.

In order to define the system requirements, data have been collected from different sources. Firstly, participation in eSchooling project offered the experience of an active working group, generating materials also from conferences and focus group activities (Giaffredo, Ronchetti, & Valerio, 2014a). Another source for requirements has been the activity related to the development of the OPLA’ platform (Ronchetti & Valerio, 2016), described in section 6.1.3. Last but not least, my working experience as a CS secondary teacher helped to draw a clearer context for collected data. All data helped me to specify the system requirements.

Then, we faced the choice between making a new system or buying an existing one. We preferred to develop a customised solution, because of the origin of our research question. As we said, the research question partially arose from results of previous research projects and activities. In order to increase the value of those research results, we decided that CoMak should be developed on a database compatible with results of eSchooling project, and in particular with the OPLA’ platform.

5.3 Design of a support system: CoMaK

This section describes requirements analysis and specification of the system. The life cycle of system development followed an incremental model. Communication for system development evolved accordingly, in order to develop the initial and general design of the system into a consistent version of CoMak. Project team had some working meetings, described by a working diary regularly sent to the bachelor's thesis advisor. Requirements specification has been detailed by materials and documents, delivered to the programmer. We report here the most relevant models.

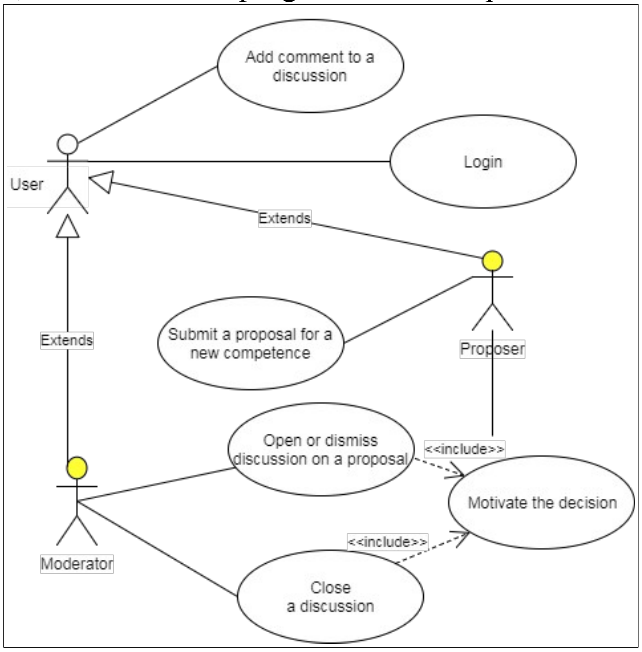


***Figure** 2: CoMak: Use-Case diagram, level 1 (translated from Italian)*

Figure 2 shows the level 1 Use Case diagram, highlighting two different roles that a user might play and the main use cases of the CoMak system. Each user is allowed to add comments to a discussion onto a proposal (also called thread). Each user might submit a proposal for a new competence, playing the role of proposer, and might also assume the moderator role. The moderator decides if a discussion on a proposal can be opened or has to be dismissed, and she/he decides as well to close a discussion. Closing a discussion means that the proposal has been either approved or dismissed by the "miniforum". In any case, the moderator motivates her/his decisions: reasons to accept or not the discussion on a proposal, and reasons to close the discussion with an approval or a dismissal. Different states of a proposal have been represented by a state transition diagram, displayed in Figure 3.

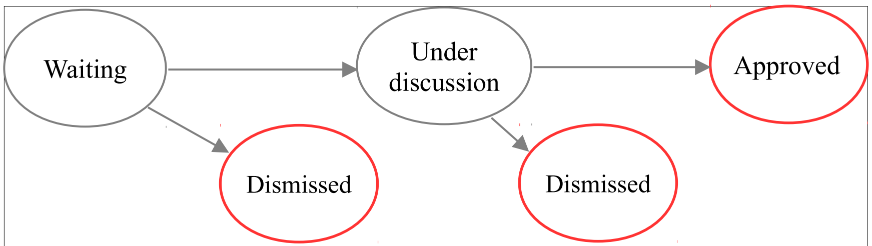


***Figure** 3: CoMak: state transition diagram for a proposal*

The data analysis produced a Class diagram. From this diagram the programmer implemented the CoMak database. The class model is shown in Figure 4.

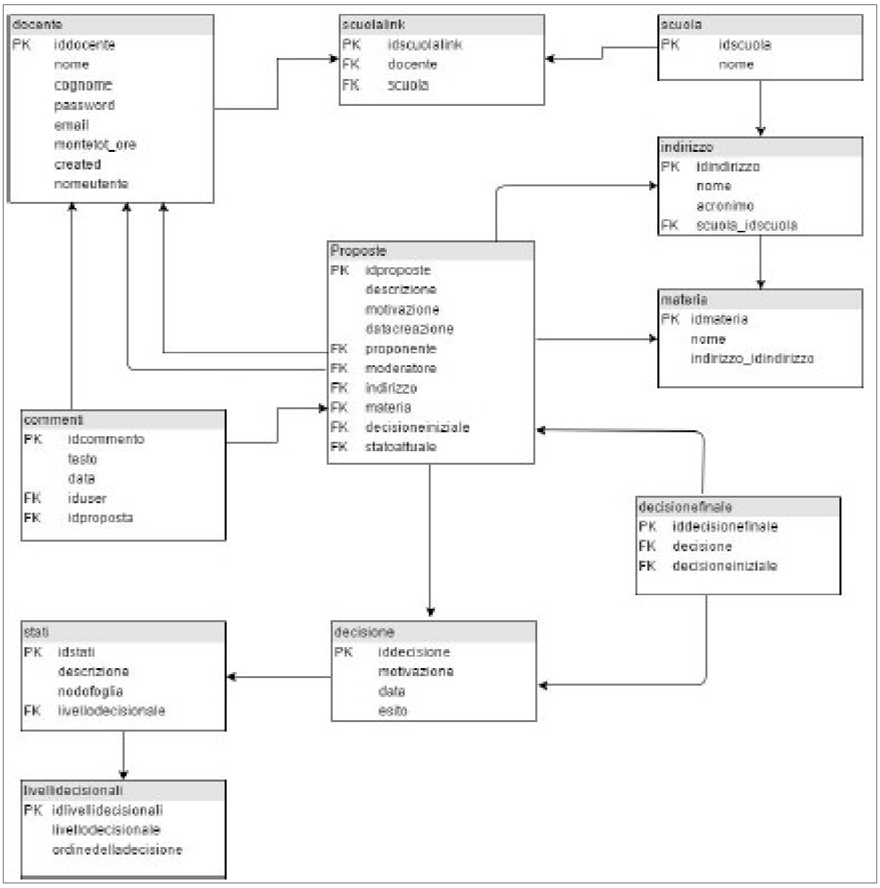


***Figure** 4: CoMak database diagram (object's names are in original version)*

5.4 Implementation of CoMaK

CoMak development was completed in April 2016. The system has been installed on a server, made available by Memetic[23]. An access to CoMak via Http has been offered to teachers involved in the training course described later on (see section 6.1.1), with the same credentials used during the course to access OPLA', the platform adopted to manage student projects (section 6.1.3). We show here some screenshots of CoMak.

23 Memetic SrL is a small Italian company: https://www.memetic.it/it/

Figure 5 shows the screen of the application to submit a proposal for the definition of a new

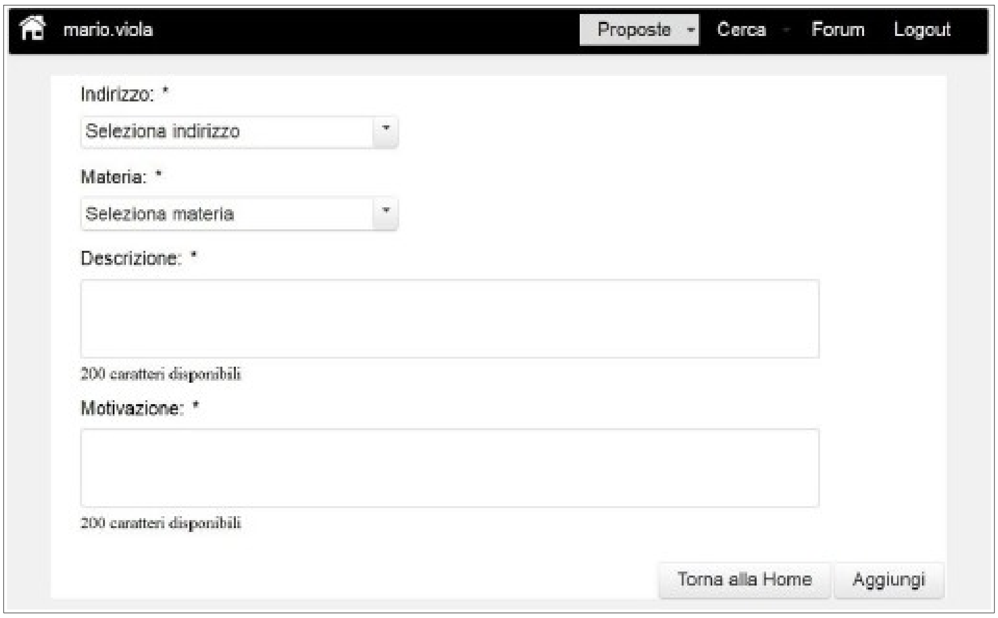


***Figure** 5: CoMak: submit a proposal for a new competences*

competence. The user chooses branch and discipline, then inserts description and motivation of the proposal, and finally submits it. The released version of CoMak does not limit the choices for users. Accordingly, each teacher is allowed to submit proposals related to any branch and discipline, regardless of the discipline taught.

The “miniforum” implemented by CoMak is given in Figure 6, displaying two proposals moderated

***Figure** 6: CoMak: proposals moderated by user* mario.viola *in the “miniforum”*

by the connected user. When a user accepts to moderate the proposal of another user, a discussion on the proposal is opened, and the users are allowed to comment on it, with no limitations deriving from branch of their school or taught discipline.

***Figure** 7: CoMak app: browse through proposals in the "miniforum"*

A research option allows users to browse though the "miniforum". The discussions can be chosen and filtered by several criteria: state, school branch, school discipline, or free text. The state of the proposal is shown by text and by a coloured icon.

5.5 Results

Teachers accounts were activated at the end of April, near the very busy final part of the school-year. Unfortunately, teachers in the experiment of the action research training course did not use CoMak, possibly due to time constraints. After the course, CoMak has been tested by two CS teachers. From those applications we gathered some useful input to improve the system interface, and to revise and extend the functionalities for the competence definitions. A suggested feature might enable users to integrate new definitions of CS competences with institutional definitions. A design for adding this feature in CoMak evolution has been drawn in section Chapter 7. The software system is available for future experiments, that should be run for example by the institute of provincial educational research IPRASE[24] or by some of the schools in Trentino to involve teachers in a process for the definition of the set of competences. Other remarks could help to understand if teachers participating in the definition process can be inspired to adopt the CBE approach.

My contribution to the realisation of CoMak includes the requirements elicitation and specification, the data and function analysis, the data design, and the project leading. The software has been implemented as final thesis of a bachelor's degree in Computer Science by a student of the University of Trento, (Kircanski, 2017).

24 Italian acronym of Istituto Provinciale per la Ricerca e la Sperimentazione Educativa

Chapter 6

Applying project-based learning method and adopting competence-based approach to education

This chapter describes the work done in order to answer the second research question:

> *Are CS secondary school teachers induced to adopt the CBE approach when they are applying the PBL method?*

Considering this research question, we needed to examine teachers when applying the PBL method in their classes. To this goal we designed two different kinds of study, which allowed us to investigate PBL activities of teachers in different contexts:

- a training course for CS teachers;
- the ordinary PBL activities of CS teachers in class.

An action research training course has been designed and realised as the first study. The second study has been setup as a set of case studies, also called collective case study. The variety of tasks included in the course and in PBL activities of the case studies offered the opportunity to observe the ongoing teaching action in a way that sometimes neither self-evaluation questionnaires nor interviews can provide, as reported for example in (Wuttke & Seifried, 2017, p. 890).

Even if it is quite common to use projects in school activities and in particular in CS, we started working on these studies knowing that student projects sometimes can not be considered a full application of the PBL method, for different reasons: for example, because projects are used "as a way to test students' understanding of materials presented in lecture" (CsTeachingTips, 2017), or because requested activities have the only goal of "doing for the sake of doing", rather than "doing with understanding" (Barron et al., 1998). Nevertheless we setup a collective case study involving student projects of six classes. Observing the class activities of the collective case study we recognised that not all the main characteristics of the PBL method were included in the student projects. Consequently, before investigating if student projects do help teachers to adopt the CBE approach, we analysed to what extent the student projects can be defined as PBL. To this goal we first defined a scheme, and finally we applied the scheme to the student projects of the collective case study.

The chapter describes separately the two studies and includes details on specific methods for the training course in section 6.1, and of the collective case study in section 6.2, the latter including the application of our scheme to the student projects. Section 6.3 closes the chapter with a synthesis of common results,.

6.1 First study: the action research training course on project-based learning

This section describes the first study, defined to answer the second research question. First subsection introduces the main characteristics of the action research course of the study. Subsections 6.1.2 and 6.1.3 describe the research method, including details on the platform OPLA' adopted as online support for trainees teachers. Details on the course have been included in the subsection 6.1.4. Subsection 6.1.5 shows the results of the first study.

6.1.1 Introduction

We designed a training course in the form of action research, referred to both the PBL method and the CBE approach. The Italian title was *Progetti e Competenze per Informatica*. The course included three different kinds of activities:

Plenary meeting. General session with the whole group of trainee teachers, gathered to attend short interventions, or to share experiences and ideas about specific students projects or the PBL method in general.

Individual project meeting. The researcher meets the teacher who is planning to apply the PBL, in order to observe and to support planning, designing, and implementing the students projects.

Individual teacher on-line education. Each teacher can access a web application, which supports and partially guides the trainee in the PBL activities.

The milestones of the course plan were three plenary meetings, set as shown by the timetable in Figure 8: the first meeting to share the working methods and to start the work of the students' groups, then to share the PBL activities designed by the attendees, and finally to compare the PBL activities delivered in classes by the attendees. Individual support was also available for trainees on demand.

Plenary meeting	19/10/15 2 hours	→ 16/02/16 2 hours	→ 25/05/16 2 hours
Individual project meeting	6 hours per project		
Individual teacher online education	3 hours per teacher		

***Figure** 8: The timetable of the action research course*

We collected data at the beginning and at the end of the course, to investigate possible variations occurred after the action research course. Seven CS teachers enrolled in the action research course. They worked in two different towns and in three different technical schools of the two different sectors, economic and technological.

6.1.2 The research method

Action research has been defined as a kind, or style, or methodology of educational research (Cohen, Manion, & Morrison, 2007). When applying the action research, the declared choice is to combine the research activity and the ordinary activity which is object of the research. For this reason, "Action research is research by particular people on their own work" (Cohen et al., 2007, p. 298), and implies a careful observation of the ordinary work. The action research usually includes four phases: planning an action; implementing the planned action; observing it; then reflecting on results. The four stages form a cycle which is usually replied in a sequence of cycles called "*self-reflective spiral*" (Cohen et al., 2007, p. 300).

We describe here the application of action research to a training course for CS teachers. As the course is on the PBL, course attendees are asked to plan their activities for the project to develop in classes. Details on the project plans are collected during individual project meetings, as well as during visits to schools and classes involved in the planned projects. The observations of the implemented action are conducted with teachers who lead the observed project, in this way forming mixed teams of teachers and researchers with focus on a single project. Mixed teams reflect as well on results, in order to plan the project steps and tune the activities to be implemented, realising the *self-reflective spiral* for each project. The individual projects have to be discussed also in the large group of all attendees, for a reflection on the various projects issues. For the large group, the course includes only one cycle of planning, implementing, observing, and reflecting.

In order to measure the impact of the training course, we introduced two tools: a worksheet called Plan for a PBL activity (worksheet) (in Italian *Modulo Pianificazione di un Progetto didattico*, see Appendix F), an Italian reduced version derived from the Project planner of Patton (Paul Hamlyn Foundation, 2012), and a web application platform. The worksheet synthesises main aspects of the plan for a PBL activity. Besides basic data like project name and class or groups involved, the sheet requires defining the learning goals, separately identifying contents and skills for the students to learn. Related to the identified learning goals, the assessment criteria for contents and skills are required as well.

The web application platform OPLA'[25] supports teachers in planning, designing, and implementing different educational activities, including PBL activity. After the initial settings of school name, teachers and students names, classes, disciplines, competences with related contents and skills, and more, teachers are allowed to define their teaching activities. Focusing on PBL activity, the project might involve different teachers, whereas students might be grouped, and the quality of the final product might also be detailed using the levels of a rubric. Furthermore, a competence rubric might be defined, related to each of the competences chosen for the project. The plan of the activities can be defined compiling a sort of Gantt diagram, with a choice of different time granularity. Assessment features include discipline-specific competences, chosen by teachers, and general competences, defined at school level.

Both tools, the worksheet and the web platform OPLA', have been used during the course in a specific way. The worksheet *Plan for a Project-based Activity* has been defined for planning the project before its implementation with classes. It can also be used after the delivering, as a re-engineering tool able to rebuild the motivation of the project, and to promote a reflection on work done. In our case the use of the worksheet has been threefold, because in different course phases we asked teachers to fill the worksheet:

- to describe past projects, delivered to past classes;

25 OPLA' has been developed by a small Italian company, Memetic SrL: https://www.memetic.it/it/

- to plan a project to deliver during the action research course;
- to simulate the plan for a possible project to deliver with future classes.

Data collected with the first set of worksheets, to describe past projects delivered to past classes, have been then analysed by two different groups of observers, using a blind-evaluation technique. As documented in (Giaffredo et al., 2017), some results of this analysis tell a lack of a shared vocabulary on the CBE approach for the teachers of the sample. Finally, the characteristics of simulated plans for future classes have been compared with past projects plans. In this way, we can record possible changing brought by the action research course, in the way teachers think their PBL activities.

The plans for the projects supported by the action research course have been uploaded to OPLA'. More details on the projects plans have been included in section 6.1.4.

6.1.3 Requirements for a competence-based platform: OPLA'

The platform OPLA' has been designed and realised following the experience of an industrial project, named eSchooling (Giaffredo, Ronchetti, & Valerio, 2014b). The web solution originated by eSchooling project supports teachers, hosting their activities in a competence-based framework. From initial school-year plan and through various class activities, teachers can always refer to the competences of the class. The eSchooling solution has been inspired by the interdisciplinary nature of the CBE approach. Accordingly, strength and weakness of the solution are heavily dependent on the cooperation level among teachers of the same class. The OPLA' project, which generated the OPLA' platform, represents an evolution of eSchooling. Vocational schools (*professionali*, in Italian) have been the incubation environment of the new project, preferred to other kinds of school for "a number of advantages [...]:

- Interdisciplinary approaches are more commonly accepted and sought;
- There is a stronger emphasis on "being able to do" rather than "to know";
- Due to a different legislation, the role of the school manager is more powerful and pronounced;
- Legislation is less ambiguous in indicating CBE as the way to go (*D.P.R. 15 marzo 2010 n. 87, 88 e 89*, 2010) and at the end of the education path the student is qualified with a professional profile that is coded into competences by law" (Ronchetti & Valerio, 2016, p. 4511).

The redesign action to develop OPLA' had a meaningful starting point: "competencies are developed while solving problems and fulfilling duties which involve practical applications of knowledge and know-how", which could even be declined into a clearer slogan: in order to develop competences, "teaching should [be] in large part project-based" (Ronchetti & Valerio, 2016, p. 4512).

Our research adopted the platform OPLA' as online support for trainees teachers of the action research course, even though some characteristics of the OPLA' project are different but complementary to our research. We highlight here three of these characteristics:

The kind of school. Ronchetti and Valerio described the situation of vocational schools (*professionali*), whereas our research took place in technical schools. In spite of what the footnote 12 at page 33 recalls, the two kinds of school have meaningful differences.

Focus on learning or teaching. Even though the two authors use the term “teaching” in their aforementioned slogan “teaching should [be] in large part project-based”, their claim suggests that students could be supported in developing competences when involved in projects at school. As a result, they highlight more the learning. The focus of our research is different because, according to the second research question of this thesis, we investigate if project-based is a method able to induce teachers to adopt the CBE approach.

Interdisciplinary approach. Whereas Ronchetti and Valerio in (Ronchetti & Valerio, 2016) highlighted the advantages of using OPLA’ in projects involving a group of teachers, working to develop competences of the same students group, our research focused on teachers in contexts where the “interdisciplinary approach” is not mandatory for project activities. In other words, on the one hand the two authors firstly found a group of teachers willing to do interdisciplinary activities, then studied the teachers at work on a project. On the other hand we firstly found teachers proposing projects to their classes, then studied the teachers at work. In my case, teachers producing interdisciplinary activities is only a chance, not the main goal I expect.

According to the objectives of our study the most interesting aspect in OPLA’ platform is the centrality of the PBL method. As described later on in this chapter, we used the platform OPLA’ in the action research course as an online tool for trainee teachers. In this way, I contributed to the platform testing. Even the second research study (see section 6.2) has been a testing environment for OPLA’ platform. Finally, during the school-year 2017/2018, I am leading the TambAttiva project[26] in the school where I teach. In TambAttiva, OPLA’ is the most relevant part of the technological structure.

6.1.4 The action research course

We designed an action research course on the use of the PBL method in CS. The training was intended to let emerge and highlight the aspects of PBL more effective for learning, and to find possible links to CS competences. The target of the action research were CS teachers, included but not limited to teachers who already planned to apply the PBL method at least in one class during the school-year. The various pedagogical environments in which the teachers were working offered a rich variety of situations to observe. IPRASE (Istituto Provinciale per la Ricerca e la Sperimentazione Educativa) has had the administrative role, for teachers having recognized the extra hours of work needed to attend the course. The course provided three different kinds of training activities: plenary meetings, individual project meetings, and individual teacher on-line education. In the rest of the section we firstly illustrate the three plenary meetings, which represent the milestones of the course plan, then we refer more details on individual meetings and on-line education.

First plenary meeting. The most important aspects of the PBL method have been reviewed, also sharing some characteristics for the design and the implementation of the student projects, which the teachers were going to plan for their classes. We used both the worksheet *Modulo*

26 TambAttiva project supports student projects at ITE Tambosi (Trento), during school-year 2017/2018. The project has been financed by Autonomous Province of Trento (PAT) as part of a funding action called AuleDigitali.

Pianificazione di un Progetto didattico, and the web application platform. The attendees filled in the worksheet with data related to past PBL activities delivered in their classes. Then, the teachers were also invited to use the worksheet to plan the real PBL activity to deliver in classes during the school-year, as required by the "action" component of the course. To the same goal we also introduced the teachers to the use of platform OPLA'. This web application has been available for trainees as an on-line guide, supporting teachers in planning, designing, and implementing a PBL activity during the training course.

Second plenary meeting. Between the first two meetings, the trainees uploaded to OPLA' the initial data of four planned PBL activities, requiring students designing and developing a software application. The four PBL activities were named *Game Making*, *NcResolution*, *FontanaSostenibile*, and *Progetto di Progetti*. With Game Making, seven groups of students in a class realized their computer game. NcResolution managed the resolution of non-conformities for a company. FontanaSostenibile was a software to enhance learning and teaching, with the aim at inspiring the awareness of sustainability. Progetto di Progetti supported the management of the work experience internships, compulsory for all the students of the last three course years. In the second meeting the main characteristics of the four PBL activities were shared. Part of the second meeting focused on the analysis of data collected in the first meeting with the worksheets. Some peer-critique techniques have been finally described and discussed, inviting teachers to use them in their PBL classes.

Third plenary meeting. It was planned as a workshop in which the teachers summarize the PBL activity implemented during the school-year. Due to the limited number of attendees, only three teachers representing two PBL activities, the workshop was turned into a discussion on some points, related to the usefulness of the PBL activity. More in details, the following questions have arisen:

1) Was the PBL activity an effective opportunity for the students to enforce their competences, achieving their individual learning goals?
2) Did the application of the PBL method inspire the teachers to adopt the CBE approach?
3) How did the teachers assess the learning process and the achievement of the learning goals for the individual students?
4) What were the advantages and disadvantages of the PBL activity for individual students working in groups, according to the teachers?

Using the worksheet *Modulo Pianificazione di un Progetto didattico*, we collected new data about the planning of a PBL activity but, differently from in the first meeting, focusing on future, possible activities to deliver to their classes.

Individual meetings involved 5 out of 7 teachers. Teachers have been encountered individually or, more frequently, in couples, as they both worked in the same class, on the same project. During these meetings teachers defined the characteristics of their planned PBL activities, which were entered into OPLA'. Then, in other meetings we agreed on specific techniques to apply in classes. For example the gallery critique protocol (Paul Hamlyn Foundation, 2012, p. 99) was applied to the Game Making activity. Some classes of the Game Making PBL activity have been observed, documenting the relevant steps, some of them by video recording. OPLA' was then used by teachers to upload and share materials. Even though the planning feature of OPLA' has not been used during the course, some teachers accessed the platform as a guideline and an inspiration for initial competence choices and rubrics, which were then part of the plan for the PBL activities.

6.1.5 Results

The first study focused on an action research training course, attended by seven teachers of three different technical schools. The teachers have planned four PBL activities for different classes. Nevertheless, only two activities have reached the design and the implementation phases: the *Game Making* and the *NcResolution*. The last plenary meeting of the action research course offered the opportunity to compare these two PBL activities of two classes, mainly delivered in CS laboratories.

The *Game Making* involved 21 students of the 3rd course year of a technical-economic school. Seven groups of students had been formed. The assignment for each group was to design and develop a computer game, inspired by real games.

The other PBL activity, *NcResolution*, engaged the 11 students of the 4th course year of the same school. The groups of students designed and developed a software application for desktop computers to manage the resolution of non-conformities for the company which had ordered the activity. Each group worked on a specific part of the application.

6.2 Second study: collective case study on student projects

This section describes the second study, defined to answer the second research question. As a collective case study we analysed six student projects in technical secondary schools to understand if teachers are induced to adopt the CBE approach when they are applying the PBL method. It is useful to underline here and again that not all student projects are PBL activities. As a consequence, in order to analyse how much a student project can be considered as a full application of PBL, we defined a scheme with the characteristics required for a project to be a PBL activity. Then we applied the scheme to the student projects of the collective case study.

Two technical schools have been requested to collaborate in this study. A letter has been sent to the school Principals of an economic technical school and of a technological technical school, in order to gain the official permission to undertake the research (Cohen et al., 2007, p. 55).

In the case of the economic school, a more detailed letter of presentation has been sent to the CS department, and its members have been also met for a short living presentation of the future visits of the researchers. Other departments have also been involved. A short presentation has been given during a meeting of the Law department. The coordinator of the Economics department has been met as well.

In the case of the technological school, two CS teachers have been directly contacted.

Next subsection 6.2.1 introduces the collective case study of six student projects, which are listed and shortly described. Subsection 6.2.2 illustrates the research method. More details on the case studies have been included in the following subsection 6.2.3. Subsection 6.2.4 introduces the scheme to analyse the characteristics of a student project in terms of PBL and the application of the scheme to the six student projects under observation. Subsection 6.2.5 shows the results of the second study.

6.2.1 Introduction

Ten teachers accepted to be involved in the research; only one was not a CS teacher. Six student projects involving 121 students of six classes have been studied in two schools, within six months. Some details of the project activities, the course year and the number of the students, are shown in Table 6.1. Each activity has been developed by one class only.

Table 6.1: Six student projects

School Technical sector	Student projects ‘ number and name (partner name, for outside commissioned projects)		No. of students	Course year
Economic (Istituto Tambosi-Battisti)	1	Garden furniture (Comune di Lavis)	18	4th
	2	Working clocking in and out management (l'Adige)	17	
	3	Audit monitoring visits (GPi Group)	21	
	4	Critical factors and quality improvement action at school[27] (Istituto Tambosi-Battisti)	21	
Technological (Istituto Buonarroti-Pozzo)	5	WikITT	20	5th
	6	TicTacToe	24	3rd

The student project number 4 was a multidisciplinary activity, involving a class of non CS students. The other projects involved only the CS subject and their teachers and students, with the goal to develop a software application. A relevant aspect distinguishes the projects of the two schools: the two projects developed at the technological school were requested by the teachers, while the projects of the economic school have been commissioned by different subjects:

- the municipality of a 9 thousand inhabitants village of the Trento province (Comune di Lavis);
- a local newspaper, based on the Trento province (l’Adige);
- a group of private companies operating in the healthcare and social services market, with more than 5 thousand workers, and headquarter in Trento (Gpi Group);
- the office of the Principal of the school itself (Istituto Tambosi-Battisti).

A short description of each student project follows here.

Student project no. 1 – Garden furniture (Attrezzature Parchi). The students have been requested to design and to develop a software application for desktop computers to manage the public gardens of the municipality. The management of the gardens involves many characteristics, including the kind of terrain, the games, the furnitures, and the ordinary and extraordinary maintenance interventions, to be planned and realised by the municipality. The application uses a relational database.

27 The full name of the project is “Inquiry on critical areas and hypothesis for quality improvement actions at school”, in Italian “*Indagine sulle aree di criticità e ipotesi di azioni di miglioramento della qualità della scuola*”

Student project no. 2 – Workers clocking in and out management (Gestione timbrature). A desktop software application has been requested to manage the clocking of the newspaper workers. The installed attendance clock devices record the clocking in and out of the worker writing into a text file, but the management of the newspaper was only able to use these data partially, resulting in a lack of information on the personnel management and in a time consuming processing activity. All the data recorded by the attendance clock devices have to be adapted to be managed by a relational database. After that, the software application offers a friendly interface to let users apply various functionalities to a structured database.

Student project no. 3 – Audit monitoring visits (Visite e verifiche ispettive). The planning and the documentation of the audit visits and their reports are the subject of the software application which students were requested to design and to develop for a desktop solution. The existing audit procedures recorded data on spreadsheets, but this was no more acceptable for the audit responsible, who decided the order commission. The new application has to manage a relational database, only partially integrated to the database of the NcResolutions application realised by a previous class of the school for another order commissioned by the same business (see section 6.1).

Student project no. 4 – Critical factors and quality improvement action at school (Criticità e miglioramenti a scuola). It is the only non-software student project included in our research. This project combines the needs of the teachers, to work on the citizenship competences with the students, and the needs of the office of the Principal, to deal with quality improvement of the school. For this reason, the activity started as an order commissioned by the Principal of the school Istituto Tambosi-Battisti to the class. The project includes design, realisation, and submission of a survey to the students of the school. The survey focuses on quality perception of teaching and school-life. In order to reach more than 300 students, the survey has been submitted using the Google Forms application of the G Suite for Education, available for staff and students of the school. The collected data have to be at first cleaned by the students, in order to remove invalid data. The following data processing does obtain the results. At the end, the presentations of the results have to be given, both to the commissioner and to other school institutions. The student project has benefited also from the collaboration with the Economics Department of the University of Trento.

Student project no. 5 – WikITT. The students of the last course year of CS branch at the school Istituto Buonarroti-Pozzo are usually asked to develop a software application during the last semester. The two involved teachers defined the general characteristic for the software to produce: a website to share video lectures in pills, created by the students for the students. The students were requested to design and develop the website and the database for it, along with the standard layout for the video lectures and the first examples of short video lectures, choosing CS topics. The student project has been also documented by a paper, accepted by a national conference (Giaffredo & Raffoni, 2017).

Student project no. 6 – TicTacToe. This student project proposed the class to study a well known game, called *Tris* in Italian. The first goal for the students to reach was to analyse the game and define proprieties and methods of the classes, representing the game. The completion of this phase of the work was required in time for the Open Doors Day of the school, to give a public presentation during the event. The implementation of the software program, to develop in C# language, was planned for a further phase.

6.2.2 The research method

The research has had different steps:

- initial interviews with the teachers, with a questionnaire available as a reference;
- direct observations of the teachers, working on their student projects;
- support to the teachers in project activities;
- use of a software application to document and to fit the project activities into the CBE framework.

Different methods have been applied in the different steps:

Initial and final interviews. To know the project activities designed for the classes, we planned an initial individual interview with the teachers. We preferred to meet the teachers individually, even for teachers involved in the same student project, because we needed to know how teachers are accustomed to the CBE approach. More in detail, we collected data on the design of the project activities: data related to competences to be developed by the student project, and data related to the ways to assess the students. Even if we prepared a questionnaire, we preferred to meet the teachers avoiding to have them fill in the questionnaires, and to address the issue talking with them. Near the end of the research at school, we met the teachers using the same scheme of the initial interviews. Also for these final meetings we preferred individual conversations with teachers (see Appendix G, PBL Experiences – Questionnaires, with both initial and final questionnaires).

Observing teachers' project activities. Over the six months of the research we met the teachers in different situations, including individual meetings, lessons in class and, more often, in the laboratories with the students. The visits for the different student projects were very different. In the meetings with the teachers we collected more details on the designs of project activities.

An overall and written plan for the project activity has been shown only for the student project number 4. In this case the initial plan lists the competences expected to be developed by the student project, specifically referred to the various disciplines involved. A first definition of the tasks assigned by the teachers and the time expected for each task to be completed by the students was included in the plan. This level of description was also due to the need to share different phases of the project among teachers of different disciplines, to coordinate the different teacher actions. The teacher responsible for the 4th student project used a model or scheme for the design. It was a personal model, not adopted by the rest of the school. The design of the assessment did not include any rubric.

The teachers of the other student projects did not show any written plan nor design for their activities. For the orders commissioned by the external subjects, it is important to add that the agreement among the school teachers and the commissioning subject is sometimes difficult to be detailed. The process of requirements elicitation is as well not easy to be realised, even because it is partially in charge of the students, who at the same time have to do and to learn this difficult work.

In the case of the student project number 5, the teachers put on the most relevant projects deadlines for students, defining with them various forms of assessment.

A clear definition of roles and objectives of group working has been given to the students, for the 6th student project, by the teacher, who partially adopted a cooperative learning approach. In this case the students worked in pairs, and received a group working assessment at each step of the work. The pairs remained the same until the end of the first activity phase.

Supporting teachers' project activities. We had the opportunity to reflect on the observed project activities with the teachers. The design of the student project, even when it was neither well defined nor written, has not been modified by the presence of our researchers. Nevertheless we discussed some small possible changes to the group working, a characteristic of all the projects. The researchers invited the teachers to partially rethink the design of the student projects, from the point of view of the CBE approach. To this aim, explicit points of reflection were: the competences chosen for the student projects, the rubrics definition, the ways to observe the students, and the tools to assess the students ‘ activity and the product of their work.

Using a software to document PBL activities of the student projects. To document the PBL activities in a structured way we planned to use a software system. Three kinds of reasons justify this solution: the quantity of data to manage, the communication needs, and the need to have a consistent management of the educational work, which can also take a really long part of the school-year. We show here more details of the three reasons.

Quantity of data. From the initial phase of didactic design, the PBL activities manage different kinds of data, mainly to define the competences rubrics. Summarizing, these are the steps for such definition:

- identify the competences to refer to, for all disciplines involved in the PBL activity;
- detail each competence, with a definition fitting the specific PBL activity;
- explicit the description of different levels to reach for each competence, in order to assess the students for the PBL activity.

During the implementation phase, a lot of data are then generated; most of them are the levels reached by students for different competences, identified by teachers.

Communication needs. Data managed by software have to be available to teachers involved in the same PBL activity. At the school’s convenience all the resources used or produced by a PBL activity might similarly be shareable among all teachers of the school.

Consistency needs. The design phase defines the characteristics of the future teaching activity. The consistency with planned characteristics should be guaranteed during the activity implementation with students at school. The consistency includes timetable and deadlines, as well as definitions of set of competences and related rubrics, which are the basis for the assessment.

The software chosen for the research was OPLA’, the platform built as a web application and described in the previous section. The application has been designed to be as friendly as possible, that is usable with little training. Nevertheless, we preferred to avoid teachers wasting time in data-entry work, in order to let them focus on the teaching work. To this goal, we used the application instead of the teachers, adding the essential data of all the student projects to the OPLA' database. This solution does not influence the results, because the teachers shared, checked and approved the data to be entered. At the same time, the teachers held the management of the student projects and the responsibility to run the education work.

6.2.3 Student projects

We refer here more details on the student projects, studied in our research, recalling that each activity has been developed only by one class. For each student project the details describe the work done by teachers and students, and observed by the researchers, including:

- The product to be realised, with a general description of the scope and the goal of the project, the final exhibition and the possible effects outside the schools.
- Contacts or feedback from the commissioner, in case of commissioned projects.
- The criteria to form the working groups and the group assignment.
- The working methods and the standards.
- The assessment of the students for their student projects.
- The attending of the student projects at school by the researchers.

For three out of four student projects developed by the economic school ITE Tambosi-Battisti the final exhibition was the presentation in a public session on the 8th of June 2017, attended also by the researcher involved in the student projects. The meeting is a yearly event, organised since 2013 by the school Principal to meet student projects developed into an organisational framework called Agreement on Informatics for Management (in Italian, *Polo Informatico-Gestionale*). The agreement framework defines that the external partners can commission the fourth classes (12th grade) of the school the development of a software product. A specific agreement is required as well for each of the commissioned projects, with the aim of sharing a detailed definition of the product requirements. The yearly meeting collects the external partners representatives, school teachers and students. The local media, newspaper and television, usually follow the event, which publicly shows the results of the developement of a software product. Some students, on behalf of the whole class, do present the product developed by the class. In some cases, the screenshots of the main functionalities of the developed application are described as well. In the 2017 meeting, two more classes of students described their products, which were not included in our research.

Student project no. 1 – Garden furniture (Attrezzature Parchi). The product realised through the project was named "GreenPark Lavis", where Lavis refers to the name of the municipality commissioning the class to develop the project. The product includes: a software application for desktop computers, managing a relational database and offering a lot of reports to print; the user manual and the technical manual, respectively for the final users and for the programmers; the name itself; a logo. The project was presented in the public session of the *Polo Informatico-Gestionale* on the 8th of June 2017

The commissioner met the class in November 2016: the first order presentation was given at the beginning of the month, whereas at the end of the month the draft of the first requirements statements were reviewed. Other opportunities to exchange feedback with the students were created later, and the commissioner met the class almost 6 times during the school-year. The commissioner was pleased with all the development steps, and at the delivery event they claimed the product could help the municipality in guaranteeing the safety of the public gardens.

The teachers defined the working groups from the beginning, but changed them frequently. Two girls were in charge for documenting the work of the different groups. The database was populated quite early, in order to simplify the testing, using realistic data. The different groups had different parts to develop. As a consequence, it was not easy to deal with the integration of the modules. To reduce the issues, the teachers pushed for defining a standard layout of the application forms, and the class helped to choose other common aspects, like styles, colours, and font of the character texts. The system testing was also conducted in class, involving all the students, while one of them took notes. In order to assess the students, the teachers prepared various tests, to be done both in classroom and in laboratory, but in both cases the tests were not connected to the student project.

The assessment of the students' work for the student project has been obtained mainly through the direct observation in the laboratory. As a teacher said, an assessment grid could be useful.

Apart from the final exhibition, for the goal of this thesis I met this student project four times: one individual meeting with the project leader teacher, and three times in the laboratory. In two lab lessons, an officer of the municipality commissioning to the project development was also present.

Student project no. 2 – Workers clocking in and out management (Gestione timbrature). The project realised a product which is a software application for desktop computers, connected to a relational database and managing the data of the workers clocking in and out. The application receives a file with the employee attendance data from the application managing the time clock. Then the application of "Gestione timbrature" verifies that data are correct. The data can be incorrect in some cases: a sequence of two "ins" or two "outs"; a too early "in", which might be overtime; and others. In case of incorrect data, the application highlights them to the user, who accesses the functionality to adjust the data. Processing correct data, the application offers a set of features and reports: work time, total of hours per worker or per working category, overtime, and more. The project was presented in the public session of the *Polo Informatico-Gestionale* on the 8th of June 2017 (see page 78).

As a first contact with the commissioner, the class visited the site in which the local newspaper l'Adige collects the employee time clock data. It was the first opportunity to have a look of the data file to manage, including the record structure with the fields and their meanings. Only the teachers kept the following contacts with the commissioner, via email.

At the beginning of the project the students worked in the big group of the class, all together. The first, relevant results of the big group have been the data analysis and the common database structure. To carry on the application development, smaller working groups were needed. As a first step, the students have been required to represent the user forms, in order to identify the main functions on which the corresponding working groups could then work. The final function analysis has been completed by the teachers. The functions have been named, marked with a number, and described, listing also the operations for each of them. The working groups descended from the defined functions, which are: importing data; checking the errors; fixing the errors; processing data to obtain results (two different functions). The members of every group had been decided by one of the teachers, who knew the students well.

Each group had a specific deadline to achieve its results. This helped to monitor the responsibility of the individual students and of the groups. The students presented the work progress report to the class, never individually but as a group. Not all the suggestions received from the classmates' opinions have been accepted and put in operation by the groups. Also the results of single groups have been recapped a few times. Each group could further subdivide the development of the assigned function, allocating it to an inner subgroup. Sometimes the teachers supported subgroups which were dealing with difficult but very specific and narrow issues. In these cases, the other students did not take part in the solutions. The initial timetable showed 60 hours for the development of the whole application. The teachers also highlighted almost two relevant issues for students to deal with: the migration from the data file toward the database tables, and the processing of date and time data types. These two points required some instructions given to the students, temporarily suspending the application development. The teachers asked the students to define the development standards. The students defined only some standards, the most useful according to them. Nevertheless, a few students did not apply willingly the shared standards.

The teachers did not prepare any test connected to the student project. As a consequence the assessment of the students' work for the student project has been obtained by the teachers mainly through the direct observations in the laboratory. The two teachers did not compare their observations immediately, because they intended to do it before the teachers meeting, convened for the final marking at the end of the school-year. Even though the teachers had defined an initial assessment grid, which was also updated during the project development, they preferred not to use it in the final phase of the work. They also claimed that the assessment grid should include some items related to the students social behaviour.

Apart from the final exhibition, I met this student project six times: two individual meetings with each of the two teachers, two meetings with the two teachers together, and two times in laboratory class.

Student project no. 3 – Audit monitoring visits (Visite e verifiche ispettive). The realised product is a software application for desktop computers, connected to a relational database and managing the data during the subsequent phases of the audit monitoring process, from the planning to the taking place of the visits. The application supports the user in planning the visits, when the user defines: which place to visit and when, the Regulation (one or several) to refer to during the visit, and also the different arguments and sub-arguments checklist connected to the chosen Regulation. The plan indicates also the auditors involved in the visits. Regulations and arguments, as well as auditors, can be however changed or updated afterwards. A reminder with the planned visit is shown after the login has been completed into the application. When the visits are taking place, the data entered at the planning time could be also updated. For example, the argument checklist can be modified. For various reasons, the final number of visits can be higher than the planned one, for example in case of exceptional audit. A motivation is required if a visit has been planned but not realised, unless re-planned before the defined deadline. Taking place the visit, date and time have to be entered. At the end of the visit, the final evaluation is required, in order to know the compliance of the system. A non-conformity action could be opened, or the situation could be accepted and then a revision of the procedure could be suggested. The management of resolution of non-conformities had been developed during the previous school-year, for the same company but by a different class and team of teachers of the same school (see the NcResolutions PBL activity, in section 6.1). The application features include also some reports on the visits, planned and realised, and then ordered according to different criteria, for example the time. The project was presented in the public session of the *Polo Informatico-Gestionale* on the 8th of June 2017 (see page 78).

The first time the students and the teachers met the reference persons of the Gpi company was also the opportunity for visiting the local site of the company. Gpi is a group of companies which has 40 branches, distributed all over Italy. It incorporated also companies from abroad, Germany and Switzerland. The employees were 700 three years ago, whereas they now are 4000. The company sells full services in the health field. The headquarter is located in Trento, and with 300 employees it covers an area of more than 3100 m^2. The group realises also hardware systems and medical tools, for example: drug automation systems, for medicines storage and management; telemedicine, with instruments for tele-monitoring; implantable prostheses, created by 3D printers. The audit function has more than 5000 working places to visit, including both stable and temporary workplaces. The contact person explained the main activities needed for the audit monitoring visits management. At the moment of commissioning the order to the school class, an audit visits diary was updated. Also spreadsheets were used to manage the data. During one of the meetings with the contact person of the company, students suggested as a possible development the adoption of the tablet technology, apparently fitting the mobility requirement. This was considered a good idea by the contact person, nevertheless the mobility application was not a priority for the order commissioned, because only a few persons (4 to 5) are nowadays sent to the visits. The students asked the contact person for a lot of details. Near the end of the student project, they showed the database designed and some features of the application to the contact person. Good feedback was received in all the meetings. For a possible, future order commission the company could ask the school to develop an integration among the Audit Monitoring Visit application and the NcResolution application.

In order to form the students working groups, we asked teachers to give the students a short self-evaluation questionnaire, implemented as a Google Forms questionnaire. The questionnaire required students to put in order their personal strengths, related to three soft-skills (creativity skills, communication skills, and practical skills) and then to rank two of their abilities in computer science, designing and coding, using a three values range. The questionnaire results, reporting the self-evaluations of every student, helped the teachers to assign students to the various groups. Three main groups were created. Two bigger working groups descended from the two main phases of the application, the planning and the taking place of the visits, and another group descended from the report printing function, a relevant feature to develop transversally for the two phases. The latter group included three students, a sort of small operative unit. The two bigger groups were further subdivided into three small operative units. Then the teachers asked the groups to define individual assignments for the single members. The students suggested having everyday a short meeting among the three main group leaders.

The data analysis has first been shared with all the students. Later on, the work progress has not been presented in front of the whole class, neither by groups nor by individual students. Rather, the teachers directly monitored the work progress of the single members of the groups. A student documented the work done by the groups, helping them to have a common starting point, and to draw the state of the work progress. Some students seemed more motivated to achieve the goals stated by the external company than to do the personal assignments given by the teachers. In some cases they showed a reduced involvement into the common work. As a result, other students tended to be overloaded by critical works.

Some practical tests have been assigned, to mark the students on the same topics developed through the student project. The tests required fixing software code. The assessments of the students have been founded also on the direct observations by the two teachers, who compared and confronted their opinions.

The researchers met this student project eight times, apart from the final exhibition: three times with the order commissioner and the class, teachers included; one individual meeting with each of the two teachers; a meeting with a teacher and two students as group leaders; three times in laboratory class.

Student project no. 4 – Critical factors and quality improvement action at school (Criticità e miglioramenti a scuola). This student project realised a lot of products: the survey questions, also in a Google Forms version; the raw data collected with the survey among more than 300 students; the validated data, obtained through a well documented data cleaning procedure; the synthesis of the data, presented as the final result of the survey to various school institutions. Also some quality improvement actions have been suggested. The students kept daily notes on the activity. In this learning diary, students also expressed their self-evaluations. The student project number 4 did not realise a software product, and for this reason it was not involved in the meeting of *Polo Informatico-Gestionale* (see page 78). Nevertheless, the activity number 4 has had a couple of exhibition opportunities. The results of the survey and study have been shown both to the Principal office staff, and to the school committee (*Consiglio dell'Istituzione*).

The Principal of the school had commissioned the order to the class. Furthermore, the teacher responsible for the student project met the Principal many times.

The student project has been designed by the leading teacher, who then proposed the activity plan to the rest of the class teachers. Not all the colleagues helped in implementing the activity. In any case, support was guaranteed by teachers of the disciplines crucial for the success, particularly besides informatics, mathematics, and economics. Furthermore, the Economics Department of the local University contributed in evaluating an old survey, as well as to build up the new one, and in supporting the work to clean raw data and to derive a meaningful synthesis of results. The leading teacher has also drawn the format of the individual relation for students to fill.

Both the self-evaluation of the learning diary and the student relation have been used as input to assess the students. Some mathematics and some economics competences, specifically required for the student project, have been assessed as well through class exercises. Internal marketing, a topic required in the student project, has also been the topic of a class test in economics. Furthermore, the citizenship competences have been assessed through direct observation during the school work.

Researchers met the leading teacher of this student project three times. In one case the meeting was in the laboratory class, with Mathematics and Informatics teachers, supervised by a University teacher.

Student project no. 5 - "WikITT". The main product realised by this project is a website, which can host short video lectures. The other product realised is the set of protocols. In order to be published on the website, a video must be compliant with the set of protocols. A template has also been produced. The class defined technical requirements, related to the structure and partially to the contents presentation. Some video lectures in pills have also been created, on the subject of Informatics. These have been the first examples, accessible for all the students of the school and useful to refine the technical standards of the video editing. The aim of the student project number 5 and the general characteristics of the product realised have had a first presentation at the Didamatica Conference (Giaffredo & Raffoni, 2017). More details of the product have been given by each student, describing the specific functionalities through individual presentations in front of teachers and class. I attended most presentations, as part of the research project designed for this thesis.

The student project has been assigned by the teachers: no other commissioner, external to the class, has been involved.

The analysis of the student project pointed out two different work sectors: the video sector, with the definition of the standards and the realisation of the first short videos, and the website development sector. Consequently, two corresponding large groups of students have been formed. The students decided autonomously which group to join. Both large groups formed sub-groups of two/three persons. Every sub-group had to clearly define its own objectives and deadlines. Each individual student of all the sub-groups had her/his personal objectives. The leading teacher supported the students, sharing with the class a table of the groups and sub-groups definition, and a grid for the objectives of the large groups, sub-groups, and individual students. The video group started working on the logo and on the name of the website. Another initial work aimed at adopting the favourite video-hosting, discussing in class a comparative study between Vimeo and YouTube. The development group decided to use GitHub[28] as project management tool. Then they chose a common layout for the user interface, also for designing the architecture of the software application, including the database. Both large groups quickly nominated a leader. The development group had a functional organisation structure, where the functions were: the database design and management, the Javascript programming, and the Html programming and CSS definition for web pages structure. The development group had an initial distribution of roles among the functions, even if later on all the members adopted also the other roles. In general, all the students of the class had the opportunity and the responsibility to autonomously participate in the group work.

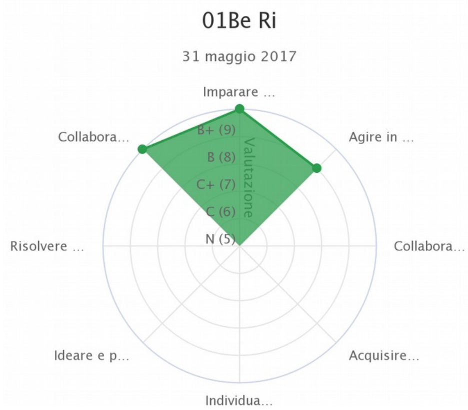
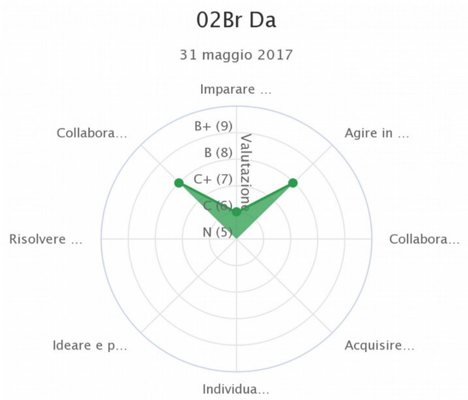
Students of both groups were required to report carefully their work, be it software development or video editing. In each lesson the students were invited to show the work done to achieve the weekly objectives. The short presentations have been marked by the teachers in a grid, which has been shared with the students. These mid-term presentations have been required for three different reasons: monitoring the student project during its development and not too late; circulating the information among the students, with the result of sharing all the information useful for the project; collecting the students marks all along the school-year, applying different and various kinds of observations by the teachers. The standards for the video editing have received relevant refinements, thanks to these presentations. A further and final presentation has also been required to each student. The final presentation introduced various points of view on the work done, discussing how the single roles had been interpreted by the students, and also pointing out the parts of the work to complete. Many students highlighted that the relationship and the collaboration among persons represented meaningful aspects of humanity, but also helped to put efficiency and high quality into the work at school. Many students appreciated work organisation and distribution, that concentrated communication among groups and with class at school, whereas a lot of work has been developed individually at home. According to the students, Google Drive has been identified as suitable not only for intergroup and infra-groups communication, but also for the communication with the teachers. The work parts dependency has been underlined as an issue for the student project.

In the initial part of the school-year, before the beginning of the WikITT student project, the standard objectives had been assessed, with related tests. For this reason, the student project has not been assessed through traditional tests. The teachers assessed the initial and the mid-term presentations, using a grid to assess the group working. A second grid has been used to assess the workload assignments and the homework. A third assessment grid has been used for final presentations. The two teachers compared their opinions and the observations of the students in action. We agreed with teachers to enter into OPLA' the data of students

28 https://github.com/

assessments, related to the student project. Adapting values used by teachers to values accepted by OPLA', we obtained some reports partially shown in Table 6.2.

Table 6.2: OPLA' - Example of two radar diagrams for social and meta-competences

Student 01	Student 02
	

To gather information on the WikITT student project for the thesis, I met teachers and students seven times: six times in laboratory class with the two teachers; one individual meeting with the leading teachers. Writing and presenting the paper at the national conference offered to researchers the opportunity to work with the leading teacher, also discussing some aspects of the student project.

Student project no. 6 – TicTacToe. The plan of this project included the design of a computer game and its implementation into a C# language program. The teacher had chosen to engage the students in the analysis of the problem, as first step in preparation of the development phases. The analysis results provided the idea for a design of the product, which the students described to the visitors during the first Open Doors Day, in December 2016. For various reasons the program was not completed in time for the subsequent Open Doors Day deadline in January, when no presentation of the project was given. After two meetings with the teacher and one visit to the class, this student project could not be further analysed so that it is not included in this thesis.

6.2.4 Student projects and project-based learning method

Working on the collective case study, we realised that the observed student projects were usually planned, designed, and implemented with limited attention to the formalisation of the various project steps. Similarly, student projects paid little attention to the main characteristics of the PBL method. For this reason, we started looking for consistent criteria able to help us to understand if and how much student projects were PBL.

To this goal we integrated the five criteria suggested by J.W. Thomas and described in section 3.2 and the main elements adopted by Patton in the Project Planner (see Appendix F). Table 6.3 shows the Thomas criteria, with a short description.

Table 6.3: Five criteria for a project to be considered an instance of PBL, authors elaboration on (Thomas, 2000)

Centrality	PBL projects are central in curriculum, not an 'enrichment' for overtime out of school

Driving Question	PBL projects focus on questions driving towards central concepts, principles, and aspects of a discipline
Constructive Investigation	PBL projects involve students, helping them to actively construct new understandings and new skills
Autonomy	"PBL projects […] incorporate [...] more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects"
Realism	PBL projects "embody characteristics that give them a feeling of authenticity"

Table 6.4 resumes the elements, proposed by Patton as a planning tool for student projects, according to PBL.

Table 6.4: The main aspects of a project, authors elaboration on (Paul Hamlyn Foundation, 2012)

Products	What do you want students to do/write/create/build?	
Learning goals	What do you want students to learn?	Identify the curriculum content that students will learn in this project.
		Identify key skills students will learn in this project. List only those skills you plan to assess
Timeline/ milestones	List the key dates and important milestones for this project. (e.g. check-ins, critique sessions, deadlines for drafts and specific product components)	
Exhibition	Exhibition venue	Where will the exhibition take place?
	Exhibition plan	How will exhibition be promoted? How will your students exhibit their work? Who will you invite?
Assessment criteria	How will you be assessing the learning goals you identified?	Curriculum content Skills

From the criteria proposed in literature and reminded in Table 6.3 and in Table 6.4, we pointed out the main characteristics of a PBL activity. The goal was to define a requirements set for student projects which is essential according to the PBL method. The set includes:

- organisational aspects, like plan and design;
- suggestions on the approach, the contents choice and the learning design, appearing under the item of driving questions and learning goals, the item of constructive investigation, and the item of realism;
- an attitude both required to the students and developed with them, the autonomy.

Finally, the requirements set has been consolidated into a scheme to analyse student projects in the light of the PBL method. The scheme shows the characteristics that should be found in the learning design and implementation of a student project to be considered a PBL activity. As a consequence, the scheme might be used as a support tool to investigate in what way student projects of computer science proposed in secondary schools do support the PBL method. Table 6.5 displays the scheme.

Table 6.5: The scheme with criteria for student projects to be considered PBL

<table>
<tr><td colspan="3">plan and design</td></tr>
<tr><td rowspan="5">driving questions and
learning goals</td><td>centrality</td><td></td></tr>
<tr><td>learning goals definition</td><td></td></tr>
<tr><td rowspan="3">learning goals assessment</td><td>self-assessment</td></tr>
<tr><td>assessment by school</td></tr>
<tr><td>external assessment</td></tr>
<tr><td colspan="3">constructive investigation</td></tr>
<tr><td colspan="3">realism</td></tr>
<tr><td colspan="3">autonomy</td></tr>
</table>

We complete here the description of the scheme adding some details.

Plan and Design. According to PBL method, a clear timeline has to be defined for the student project, and milestones have to be announced to students.

Centrality. Projects have to focus on questions which are part of the curriculum, and questions have to drive towards central concepts and principles of CS discipline.

Definition of learning goals. Curriculum content and skills which students will learn in the project are part of the learning design, and need a formal definition.

Assessment of learning goals. Learning goals assessment includes three different kinds: self-assessment which students have to do; school assessment, mostly done by teachers proposing the project; and external assessment, by people outside the school, i.e. citizens, business people, experts.

Constructive investigation. Students have to actively be involved in "doing with understanding" (Barron et al., 1998), also called learning when or by doing.

Realism. Projects have to simulate a realistic activity, primarily engaging students in obtaining a product required or useful to someone.

Autonomy. Students are required to show products of their projects. Exhibitions are usually planned. A positively given exhibition is a proof of autonomy.

The scheme has then been applied to the six student projects of the collective case study. The last section of the chapter, section 6.3, includes the results of the scheme application to the student projects, described as well in (Giaffredo, Mich, & Ronchetti, 2018).

6.2.5 Results

The second study focused on a collective case study, involving six student projects designed by ten teachers in six classes of two technical schools. Five out of six were CS projects. Only one project did not reach the implementation phase.

Observing various student projects we realised that sometimes they are designed with reduced attention to the formalisation required and the guidelines suggested by the PBL method. Consequently, we had new and unplanned questions:

Are student projects PBL activities? How much are student projects PBL activities?

To define a tool to measure the PBL level of a student project, we firstly introduced a scheme (see section 6.2.4) which includes the main characteristics of the PBL method. Then we applied the scheme to the student projects of the collective case study. Table 6.6 summarizes the results of this application. The more a project conforms to the criteria, the more that project can be considered a PBL, with the following evaluations:

- A, highly conforming to criterion;
- B, conforming to criterion;
- C, poorly conforming to criterion;
- N, not conforming to criterion.

A, B, C represent decreasing values, accepted for projects and related to the criteria in the PBL scheme. For example if project α scores A value on centrality, and project β scores B, it means that learning goals of project α are part of the curriculum more than learning goals of project β. Value N means that project does not conform to the criterion.

Table 6.6: PBL characteristics of the six student projects

			Student projects					
			1	**2**	**3**	**4**	**5**	**6**
plan and design			*C*	*C*	*N*	*B*	*C*	*C*
driving questions and learning goals	centrality		*A*	*A*	*A*	*C*	*A*	*A*
	learning goals definition		*C*	*C*	*C*	*A*	*C*	*C*
	learning goals assessment	self-assessment	*N*	*C*	*N*	*N*	*B*	*N*
		assessment by school	*C*	*C*	*B*	*N*	*N*	*B*
		external assessment	*C*	*C*	*C*	*C*	*C*	*C*
constructive investigation			*A*	*A*	*A*	*A*	*A*	*A*
realism			*A*	*A*	*A*	*A*	*A*	*B*
autonomy			*B*	*B*	*B*	*B*	*A*	*B*

Apart from project 4, five student projects show to similarly conform to the characteristics of plan and design, centrality, and learning goals definition. None of them had a written plan or a design.

Observing the projects, these activities were overlooked partially owing to the long process needed to detail the agreement between the school and the commissioning subject or company. These five projects focused on main principles of the discipline, highly conforming to the centrality criterion, but with a poor definition of learning goals.

On the other hand, project 4 defined a plan and design, partially conformed to the centrality criterion for involved disciplines, and it was the only one including a clear learning goals definition. Learning goals have been poorly assessed in all but project 5 with self-assessment, and projects 3 and 6 with an assessment by the teachers.

External assessment was implicitly applied to the projects presented to the public (projects 1, 2 and 3).

The best results were achieved for the last three criteria: realism, constructive investigation and – even if to a lesser extent – autonomy.

6.3 Discussion

This chapter has described the work done to answer the second research question:

> *Are CS secondary school teachers induced to adopt the CBE approach when they are applying the PBL method?*

The research question required to examine teachers applying the PBL method in classes. To this goal we completed two different studies in different contexts:

- an action research training course for CS teachers;
- a collective case study on the ordinary PBL activities of CS teachers in class.

The two studies have been different but complementary research activities. On the one hand, they were different in impact on teachers behaviour. The training course included sharing some basic principles with teachers, then supporting them in their practical application in classes. For this reason a goal of the course was to modify in some measure the way the teachers practice PBL, helping them to pay attention to CBE approach.

With the collective case study, on the contrary, we did not try either to modify or to interfere with teachers applying the PBL method in their teaching. It was an opportunity for us to observe the project teaching in action: we did not offer any suggestions, interacting with teachers only to collect data for the research, with no intentional consequences on teachers' training.

On the other hand, the two studies were complementary because they provided comparable results corresponding to different viewpoints. Both studies confirmed that in PBL activities teachers are specially careful to survey the social competences and meta-competences, also called transversal competences, of their students. Both teachers of the action research course and teachers leading the projects of the collective case study highlighted that PBL activities support students in developing also competences other than CS competences.

The direct observation in class and the evaluation of final products provided teachers of the action research course with the elements to form an opinion in order to assess students. About the effectiveness of the PBL activity, the teachers concluded that different students behave in different ways. The PBL activity represented a useful opportunity for all the students, and resulted very positive for some of them. The teachers did not report any negative aspect, whereas they highlighted the following positive aspects: motivation, autonomy, enthusiasm, and no defeatism. Participating to the creation of a real product was intriguing for all students.

Teachers of the collective case study developed six student projects. We were not allowed to force teachers to strictly use the PBL method. As the application of our scheme revealed, the six student projects included the main characteristics of the PBL method, but the definition of learning goals was poor and the assessment focused mainly on transversal competences rather than on CS competences. With this weak attention to assessment we can not claim that the analysed student projects were fully PBL. Consequently the results do not allow to say if, by applying the PBL method, CS teachers are induced to adopt CBE approach. In summary, attention to development of transversal competences seems to be a result of student project activities, which require more work on definition of learning goals and on assessment.

Chapter 7

Conclusions

This chapter describes the results of all the activities of our research. The chapter highlights also the possible impact of the research, finally it describes future work and open questions.

7.1 Research results

Educational institutions suggest an education system shaped by the CBE approach. Nevertheless this approach is scarcely adopted by Italian teachers. This limited adoption has been the research problem we addressed. To specify the research problem, we started from the analysis of teachers interviews through the initiative "Conversation on the Competence-based approach to Education" (Giaffredo et al., 2017), that confirmed several issues: unclarity in definitions of the set of competences; lack in teachers' competence vocabulary; limited adoption of CBE approach.

The result on unclarity is not new. A research published in 2013 claims that even scholarly definitions of set of competences are often unclear. For example "sometimes experts missed to identify a competence in the textual descriptions" (Magenheim et al., 2013). Similarly, institutional definitions of competences can also be unclear. As regard our research, all teachers interviewed reported to know the definitions of the set of institutional competences. Nevertheless, due to uncertainty about their role competences are sometimes perceived only as an obligation to comply with. At the same time, the adoption of the institutional set of competences is not mandatory. Partially due to the unclarity, a second issue arose: a lack of vocabulary on competences, confirmed also by blind evaluation on plans produced by teachers of the action research course. Twenty-eight declarations of learning goals provided by the teachers have been analysed by two blind evaluators teams, respectively of University of Milan and of University of Trento. In 4 cases out of 15 learning goals which teachers declared as *contents* have been interpreted as *skills* by the majority of the blind evaluators (Giaffredo et al., 2017). Finally, CBE approach was not homogeneously adopted by CS teachers of interviewed sample, confirming that it is scarcely used as a practical reference for teaching activities.

Starting from the research problem – the CBE approach is limitedly adopted – our research focused on solutions able to support the adoption of this approach by the CS teachers in Italy. Two research questions have been defined:

First research question: *Are CS secondary school teachers encouraged to adopt the CBE approach when they are involved in the definition of the set of competences?*

As a first step, we developed the CoMak (Competence Maker) web application to engage teachers in the definition of the set of competences. The application has been tested by a small sample of CS teachers. Even though results are not conclusive and we can not yet say if teachers can be encouraged by this participatory process to adopt CBE, teachers involved have paid attention to the institutional competences. Our first experiment provided a hint: teachers might prefer to address the CBE approach integrating their customised definition of competences and institutional definition of competences. Another reason why teachers scarcely used the application could be that the deployment of CoMak occurred near the final part of the school-year, usually very busy for teachers. As a consequence, teachers in the action research experiment did not use CoMak. Nevertheless, in the subsequent school-year CoMak was tested by two CS teachers, who gave some suggestions to improve the user experience.

Second research question: *Are CS secondary school teachers induced to adopt the CBE approach when they are applying the PBL method?*

We tried to answer this question through two studies, in different contexts: an action research course, and a collective case study. Both studies reported a weak *induction-effect* from PBL activities to the CBE approach, even though some teachers showed to be interested in applying project tools to the CS competences. The project plans are usually scarcely formalised. Furthermore, we found that student projects are not fully PBL-compliant. To address the question of the PBL-compliance, we built up a scheme to measure how student projects are PBL. When we applied the scheme to six student projects, the test confirmed a poor formalisation of plan and design, which also revealed a poor definition of the learning goals in the student projects. Our hypothesis to be investigated is that a more formalised student project could better induce teachers to adopt the CBE approach.

The two studies realised through the action research course and the collective case study offered different contexts of investigation. Action research course attendees shared some basic knowledge, principles and reflection. On the other hand teachers of different student projects included in the collective case study did not plan shared activities. The course pushed teachers to enrich their PBL activities with some aspects of CBE approach, while collective case study did not offer support to the teachers.

For the action research course, all the enrolled teachers declared to be satisfied with this training activity. To this goal, the IPRASE delivered an anonymous satisfaction survey questionnaire to the teachers, at the end of the course. To measure the impact of the action research course, we asked teachers to provide two PBL activities plans: plans of past activities, in the first meeting; plans for future activities, in the last meeting. We collected comparable data submitting the same worksheet (see Appendix F), which requires to define the PBL activity learning goals and to identify contents and skills separately. In the final plan teachers paid more attention both to the definition of the learning goals, including a social competence, and to the assessment criteria, adding also a test based on finding and fixing errors in a piece of software. One teacher included a rubric with the criteria to assess competences and skills of the students. In the last meeting we collected data of only two PBL plans. In order to guarantee an acceptable level of anonymity to the teachers, we avoided to identify them. As a result, we are not able to detect possible changes in attendees, encouraged by the action research course. Three teachers accessed the platform OPLA', sharing materials and documents. As student projects might sometimes suffer from lack of designing and planning, teachers did not use other functionalities provided by OPLA’ to manage project planning, the rubrics for competences and products, and competence assessment. Consequently, in these conditions support systems have a limited impact on educational activities.

As regard the results of collective case study, observing the project teaching in classes we can confirm that the application of the PBL method could effectively drive the learning process, helping teachers to monitor students activities. Consequently this could have a meaningful *induction-effect* from student projects to the CBE approach.

CS teachers use student projects with their pupils, even though activities are not always compliant to the PBL method. Sometimes, student projects might suffer from lack of designing and planning. In this case, support systems would have a limited impact on educational activities. Furthermore, some student projects do not focus on the specific competences of the CS discipline, neither in design nor in assessment. Nevertheless, we observed that student projects encourage teachers to assess social competences and meta-competences, also called transversal competences. In our opinion the reason is that, during the student projects, students are usually engaged in group working activities, an environment suitable to observe social competences.

7.2 Possible research impact

This subsection describes some effects derived from the work illustrated in the thesis. First, we shortly discuss further applications of the scheme we built to measure the PBL characteristics of a student project. Then we display possible consequences and implications for a number of stakeholders, including at a personal level the author himself, teachers involved in related research, schools and their management, and the institute of provincial educational research (IPRASE).

The scheme to measure the PBL characteristics of a student project could be used as a tool to support the design of student projects, helping teachers to clearly include the definition of some convenient milestones. In the first phase, teachers could apply the scheme to analyse their previous student projects from the point of view of the PBL method. This could help them to understand which parts of the project plan need to be better formalised. Their future student projects should consequently have a clearer learning design. This might be a way to drive an explicit adoption of the CBE approach.

In the following part of the subsection we introduce other implications of our research, describing them according to the persons and subjects who could benefit from the research results.

The author, a CS teacher. This research confirmed some of the difficulties encountered in teaching, the first time I met the CBE approach. The research drove me to consider in detail the concept of CBE, to analyse the choices of educational institutions in Italy, and to weigh up the solutions which other education systems have adopted. The involvement of teachers in the research has enabled a comparison among various effects on schools of the reform finalised in 2011, which introduced the CBE approach in the Italian system of education. The research activity and the practice of teaching do not always sit well together, but considering them in unison can result in positive effects, both professional and human. The research offers the practising teacher a new perspective on his/her practice, with a more informed view.

Teachers. The teachers involved were keen to compare their experiences and they willingly brought the perspective of their own work into the research. Taking part in the training on PBL, they shared techniques and approaches to design and direct the activities in class. Thanks to the observations of the researchers, they were able to reflect on their teaching approaches, both past and present. Some of them said that they would be more confident in using teaching support systems introduced during the research. This in turn can help to support the CBE approach.

Schools and management. With the agreement of principals and management four schools made themselves available for the action research training course and for the research on the topic of CBE approach. Even though the CBE approach is not new and has been stated by the law, it is not usually adopted in schools. Subsequent to our case studies research, one school acquired the platform OPLA' to support the management in pushing for a widespread application of CBE approach. The adoption of OPLA' is part of the initiative "Tambattiva" of the school-year 2017/2018, funded by P.A.T. through the AuleDigitali action. The main goal of "Tambattiva" is the management of the PBL activities of the school, involving almost 6 teachers, 3 classes, and around 50 students.

The institute of provincial educational research (IPRASE). The institute accepted the proposal of the action research training course *Progetti e Competenze per Informatica*, because IPRASE supports the adoption of CBE approach and it is trying to offer more training opportunities to CS teachers. IPRASE might repeat the training course, which had the satisfaction of the participants. Further editions of the course could help to build up a local interest group of principals and teachers, promoting the PBL method as a support for CBE approach.

7.3 Future work and open questions

We introduce some questions which remain open:

- Do CS teachers define learning goals correctly in terms of CS competences, when they design and implement student projects?
- Are student projects always PBL activities?

Future work has also to address the implementation of other functionalities, both in OPLA' and in CoMak, and then the integration of the two software systems. In the following, the design for possible evolutions of CoMak software system and OPLA' platform are described.

CoMak and OPLA'. CoMak Software system and platform OPLA' could integrate their functionalities, even though the two systems have at present two independent applications. Till now, before CoMak delivery at a given time called *time 0* a copy of OPLA' database (OPLADb) should be done, called OPLAcloneDb. CoMak does not use all the data of this database, but only data of schools, kinds of schools, and disciplines. As a consequence, in a following moment called *time 1* a specific database CoMakDb should be created from a partial view of OPLAcloneDb. Then CoMak application accesses the CoMakDb and does not use the

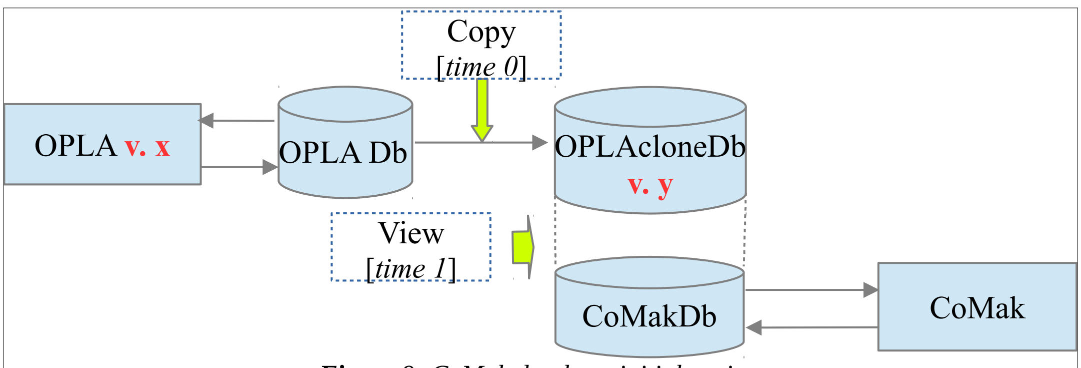


***Figure** 9: CoMak database initial setting*

OPLADb. Platform OPLA' and software system CoMak remain independent. The initial setting of the CoMakDb, database of CoMak system, has been shown in Figure 9.

Besides social-defined competences, CoMak should host institutional competences as well. Even though this solution has not yet been planned, it would only require a different view to be apply at *time 1*. Another solution seems to be more reasonable to provide: extending platform OPLA' to include the functionalities offered by CoMak.

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APPENDICES

This section collects the most important materials used for the research described in this thesis. Most materials have been originally produced in Italian language, as participants in the research are Italian school teachers. Most documents reported here have been translated into English.
All interviews have been also audio recorded, and a digital copy of the handwritten notes is available as well.

A) Competences in technical schools: area of general education

The following table shows the competences stated by the decree n. 88 (*D.P.R. 15 marzo 2010 n. 87, 88 e 89*, 2010) for the common disciplines (in Italian, *insegnamenti comuni*) of the technical schools: Italian language and literature, English language, history, mathematics, law and economics, integrated sciences (earth science and biology), gym. This set of competences specifies the learning outcomes for the subjects which all the students of the technological sector have to study.

For the other technical sector, called economic sector, the stated list of competences is almost the same. Only one competence of the technological list is not included in the list of the economic sector: it is "Using the main concepts of economics and management of the production processes and of the services", corresponding to the competence number 15 and grey highlighted in the table.

1. Evaluate facts and guide their own behaviour on the basis of a system of values compliant with the Constitution principles and with the international charters on human rights. 2. Use the lexical and expressive heritage of the Italian language according to the communication needs of different contexts: social, cultural, scientific, economic, technological. 3. Define links among cultural traditions of local, national and international scope, both in an intercultural perspective and with the goal of mobility for study and work. 4. Use cultural and methodological tools to address with a rational, critical and responsible attitude the reality, its phenomena, its problems, also to lifelong learning. 5. Acknowledge the geographical, ecological, and territorial aspects of the natural and anthropic environments, the connections with the demographic, economic, social, and cultural structures and the transformations during the time. 6. Acknowledge the value and the potential of the artistic and environmental goods, to use and to enhance them adequately. 7. Use and realise visual and media communication tools, also according to the expressive strategies and to the technical tools of the network communication system. 8. Master English language and, where required, another communitarian language to communication purposes and use sectorial languages of the specific study path, to interact in different professional scopes and contexts, at B2 level of the Common European Framework of Reference for Languages (CEFR). 9. Acknowledge the communicative, cultural and relational aspects of the body expression and the relevance of the practice of motor-sports activity to the individual and collective well-being. 10. Use language and methods of mathematics to organise and properly evaluate qualitative and quantitative information. 11. Use the strategies of the rational thought in the dialectic and algorithmic aspects to deal with difficult situations, developing adequate solutions. 12. Use concepts and models of the experimental sciences to investigate social and natural phenomena and to interpret data. 13. Use networks and information technology tools as a support in the activities of study, research, and in-depth study. 14. Analyse value, limits and risks of various technical solutions for social and cultural life, focusing specifically on safety in places of work and life, on protection of people, environment and territory. 15. Use the main concepts of economics and management of the production processes and of the services. 16. Correlate the general historical knowledge to the developments of sciences, technologies and techniques in the specific professional fields.

17. Identify and apply methodologies and techniques of project management. 18. Draw up technical reports and document the individual and group activities concerning professional situations. 19. Identify and use the most appropriate communication and team working tools to intervene in the organizational and professional reference contexts.

B) Competences in two branches of the technical schools

The following tables, translated from Italian, show the competences stated by the decree n. 88 (*D.P.R. 15 marzo 2010 n. 87, 88 e 89*, 2010, pp. 56 & 70) for two branches: the AFM (Administration, Finance, and Marketing) branch of the economic sector, and the Computer Science and Telecommunication branch of the technological sector.

ECONOMICAL SECTOR: COMPETENCES FOR THE AFM BRANCH
BE1) Recognise and interpret: - the local, national, and global markets trends also to understand the impacts in a given context; - the national and international economic macro-phenomena to connect them to the specificity of a business; - the changes of the economic systems in the diachronic dimension through the comparison among historical periods and in the synchronic dimension through the comparison among geographical and cultural areas BE2) Identify and access the public, the civil, and the fiscal legislation with particular reference to business activities BE3) Interpret business systems through their models, processes, and information flows, related to different business types BE4) Recognize different organizational business models, documenting the procedures and searching for effective solutions in stated situations BE5) Identify the characteristics of the labour market and collaborate in the human resources management. BE6) Manage business accounting system, using programmes for the integrated accounting system BE7) Apply the principles and the tools of the programming and management control, analysing the results BE8) Position the marketing activity into the business life-cycle and developing applications related to specific contexts and different market politics BE9) Effectively approach the market of the insurance and financial products, also to collaborate in finding cost-effective solutions BE10) Use business information systems and the tools of business integrated communication, in order to implement communication in different contexts BE11) Analyse and produce the documents for the social and environmental reporting, in the light of the corporate social responsibility criteria

TECHNOLOGICAL SECTOR: COMPETENCES FOR THE CS AND TELECOMMUNICATION BRANCH
BIT1) Choose devices and tools according to their functionalities BIT2) Describe and compare the functioning of electronic and telecommunication devices and tools BIT3) Manage projects according to procedures and standards, based on the quality and safety management system BIT4) Manage production processes related to business functions BIT5) Configure, install, and manage data and networking processing system BIT6) Develop computer applications for local networking or remote services

C) Plan for interviews (conversations)

This plan for interviews (conversations) has been defined to support the initiative "Conversation on the Competence-based approach to Education", according to research methods[29]. Almost ten interviews have been planned.

Plan for interviews on Competence-based approach to Education
Conversations with computer science teachers

Conversation guide
With the aim at having effective interviews, a Conversation guide sheet has been prepared. It is a general scheme able to support the researcher in conducing the interview, in order to keep useful information for the inquiry.

Conversation transcript
The conversations have been authorised in written form by each interviewed teacher. The audio has been also recorded by a digital device, when authorised by the interviewee. The privacy has been respected, because interviewees have been referred to as Teacher 1, Teacher 2, and so on. During the interviews, the interviewer took written notes as well.

Analysis of the collected materials
The collected materials are rough and need to be processed. The researcher reads and orders the conversations notes, listening audio tracks in order to integrate the written notes. The revised notes are then organised and structured, in order to reduce the redundancies and the digressions, as well distinguishing between essential and less essential parts. The goal is to get evidence of what is the way the interviewee understand the argument, even if the interviewer could also highlight new or different interpretation.
Finally, the processed materials are recombined according to some categories, which help in analysing the meaning of the collected answers.

Verify the results
The results of the analysis need to be verified against some parameters: the results consistence and the validity, i.e. the reliability of the results in representing the phenomenon.

Final report
A final report refers the results, also documenting the working methods.

29 Some references for the plan:
Cairns, Paul; Cox, Anna L.. Research Methods for Human-Computer Interaction (1st ed.). Cambridge University Press, New York, NY, USA. 2008.
Creswell, John W. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications, London, 2003.
Kvale, Steinar *Interviews: An Introduction to Qualitative Research Interviewing*. Sage Publications, Thousand Oaks California, 1996.

D) Information sheet and informed consent

The information sheet and the informed consent form have been defined to support the initiative "Conversation on the Competence-based approach to Education". The interviewees received the information sheet, read before the interview. Then they were required subscribing the informed consent form. The two documents are shown here, in their original Italian versions.

Progetto di ricerca

Università di Trento – Dipartimento di Ingegneria e Scienza dell'Informazione
Scopo: valutare l'uso della didattica per competenze nell'insegnamento dell'Informatica, nel triennio finale delle scuole tecniche

Informativa

Le chiediamo di partecipare a un colloquio/intervista, relativo allo scopo del progetto di ricerca. L'intero incontro durerà circa 60 minuti.

Ricordiamo che non esistono risposte corrette e risposte errate. Infatti il nostro interesse e' quello di raccogliere, grazie al colloquio, l'opinione degli intervistati.

Prima di procedere, Le chiediamo cortesemente di leggere attentamente e firmare un modulo di consenso.

Per motivi di analisi, Le saremo grati se ci consentirà di registrare l'audio del colloquio.

Prima di iniziare e durante il colloquio, può porre qualunque domanda agli intervistatori.

Grazie!

Se vuole avere maggiori informazioni riguardo all'obiettivo della ricerca e ai risultati finali, può contattare il gruppo di ricerca al seguente indirizzo:

silvio.giaffredo@unitn.it

***Figure** D.1: Information sheet (*Informativa*, in Italian)*

Progetto di ricerca

Università di Trento – Dipartimento di Ingegneria e Scienza dell'Informazione
Scopo: valutare l'uso della didattica per competenze nell'insegnamento dell'Informatica, nel triennio finale delle scuole tecniche

Modulo di consenso

Io sottoscritto/a ________________________________ dichiaro di partecipare liberamente e volontariamente al colloquio per il progetto di ricerca. L'obiettivo e il contenuto del progetto mi saranno spiegati esplicitamente prima dell'inizio della sessione di colloquio.
Dichiaro di avere il diritto di mettere in discussione qualunque parte del colloquio e di poter recedere in qualsiasi momento, senza alcuna conseguenza contro la mia persona.

Le informazioni raccolte durante l'incontro verranno analizzate dal gruppo di ricerca e potranno essere pubblicate e presentate ad un pubblico. Se questo accadrà, il miei diritti alla privacy verranno conservati; ad esempio, non verranno comunicati dettagli personali e non sarà possibile recuperare alcun dato che possa rivelare la mia identità.
Affinché l'analisi e la pubblicazione siano permesse,

Autorizzo	Non autorizzo

(Barrare una delle due caselle, in base alla scelta)

il gruppo di ricerca ad utilizzare i dati raccolti durante la sessione.

Per motivi di ricerca, verrà registrato l'audio del colloquio. Fintanto che la registrazione sia permessa,

Autorizzo	Non autorizzo

(Barrare una delle due caselle, in base alla scelta)

il gruppo di ricerca a registrare l'audio del colloquio.

Dichiaro di aver letto e capito quanto presentato:

____
(Firma del partecipante e data)

Membro del gruppo di ricerca che ha illustrato il progetto e condotto il colloquio:

____
(Firma del ricercatore e data)

***Figure** D.2: Informed consent form (*Modulo di consenso*, in Italian)*

E) Conversation guide sheet

The conversation guide sheet has been defined as a basis for semi-structured interviews, to support the initiative "Conversation on the Competence-based approach to Education". The text of the sheet is shown here translated from original Italian version.

Guide for conversations with Computer Science teachers
Conversation on the Competence-based approach to Education

Introducing the topic of the inquiry
We are researching on the use of the Competence-based approach in Computer Science teaching, in the final triennium of the technical schools. The research is mainly interested on the discipline specific competences.

Describing the conversation
It will be an informal conversation with serious contents, lasting around one hour, anonymous: to this end, the interviewee will be referred by a univocal but anonymous name, i.e. Teacher 1, Teacher 2, and so on. The interviewee accepts the interview subscribing the Informed consent, possibly accepting as well the audio recording of the conversation via digital device.

Some Metadata:

Kind of school of your work	
no. of teaching years	□ < 5 □ >= 5 & < 10 □ >= 10 & < 20 □ > 20
teaching at the initial biennium in the last 3 years	
Technical-practical teacher (in Italian, ITP)?	

Conversation contents
The term "competence"

A word heard at school? *[Official communication (Ministry, local research institutions, School Principal) or non-official communication]*	
What is the meaning you know?	
How could you define it to people outside the education environment?	

[in case of non-negative answer to almost 1 of the 2 previous questions]
Do you use the term/concept of "competences" in your work?
[in case of **non**-negative answer to the previous question]

What is the frequency of use? *[always, sometimes; voluntarily or when requested]*

Which definition of competence-based approach to education do you refer to? *[precise: Ministry, local Institutions, School, other]*

Do you know the discipline-specific competences of your subject?

Do you use a scheme of the competences? Is it your personal scheme?

In your opinion, which are the strengths of a competence-based approach to education?

In your assessment activity, how do you arrange with a brilliant/problematic/Specific Learning Difficulties student? Do you use the competence-based approach?

How do you combine the competence-based approach to education with your working-plan?

In your opinion, which aspects of the competence-based approach to education are:
- specific of your discipline
- related to the disciplines of the school branch
- general for all the disciplines

Did you find any trouble in applying the competence-based approach to education? Which were the main troubles?

How did you deal with the troubles? [individual/with others work; literature/institutional references, materials by colleagues, or others]

How did you overcame/are overcoming the troubles?

Could some support be/have been useful for you?

[in case of **negative** answer to the previous question]
In your assessment activity, how do you arrange with a brilliant/problematic/Specific Learning Difficulties student?

[for all]

Have you ever used the basic-competences certificate (in Italian, *pagelline per le competenze*)?	
Have you ever discussed competence-based teaching with colleagues? *[of this, other school]*	

Final
Are there questions/observations?

***Figure** E.1: Conversation guide sheet*

F) Plan for a PBL activity (worksheet)

Plan for a Project-based Activity

Adapted by "Work that matters - The Teacher's Guide to Project-based Learning" [Patton 2012]

Project Name: ....

Teacher(s): ....

School Subject(s): ....

Class/Group: .... **School-year:** ....

1. Project summary

What are your students going to do, and why are they doing it?

2. Essential questions

An essential question should:

- inspire students
- require them to conduct serious research
- relate to a real world issue

3. Products

What do you want students to do/write/create/build?

4. Learning goals

What do you want students to learn?

*[Identify the **curriculum content** that students will learn in this project]*

*[Identify key **skills** students will learn in this project. List only those skills you plan to assess.]*

Figure F.1: PBL activity worksheet (page 1)

Plan for a Project-based Activity 2
Adapted by "Work that matters - The Teacher's Guide to Project-based Learning" [Patton 2012]

5. Timeline/milestones
List the key dates and important milestones for this project.
(e.g. check-ins, critique sessions, deadlines for drafts and specific product components)

6. Personalisation
Say how you will personalise the project, especially for individual students who will need specialized support

7. Exhibition venue
Where will the exhibition take place?

8. Exhibition plan
How will the exhibition be promoted? How will your students exhibit their work? Who will you be inviting?

9. Assessment criteria
How will you be assessing the learning goals you identified in section 4?

Curriculum ***Contents***:

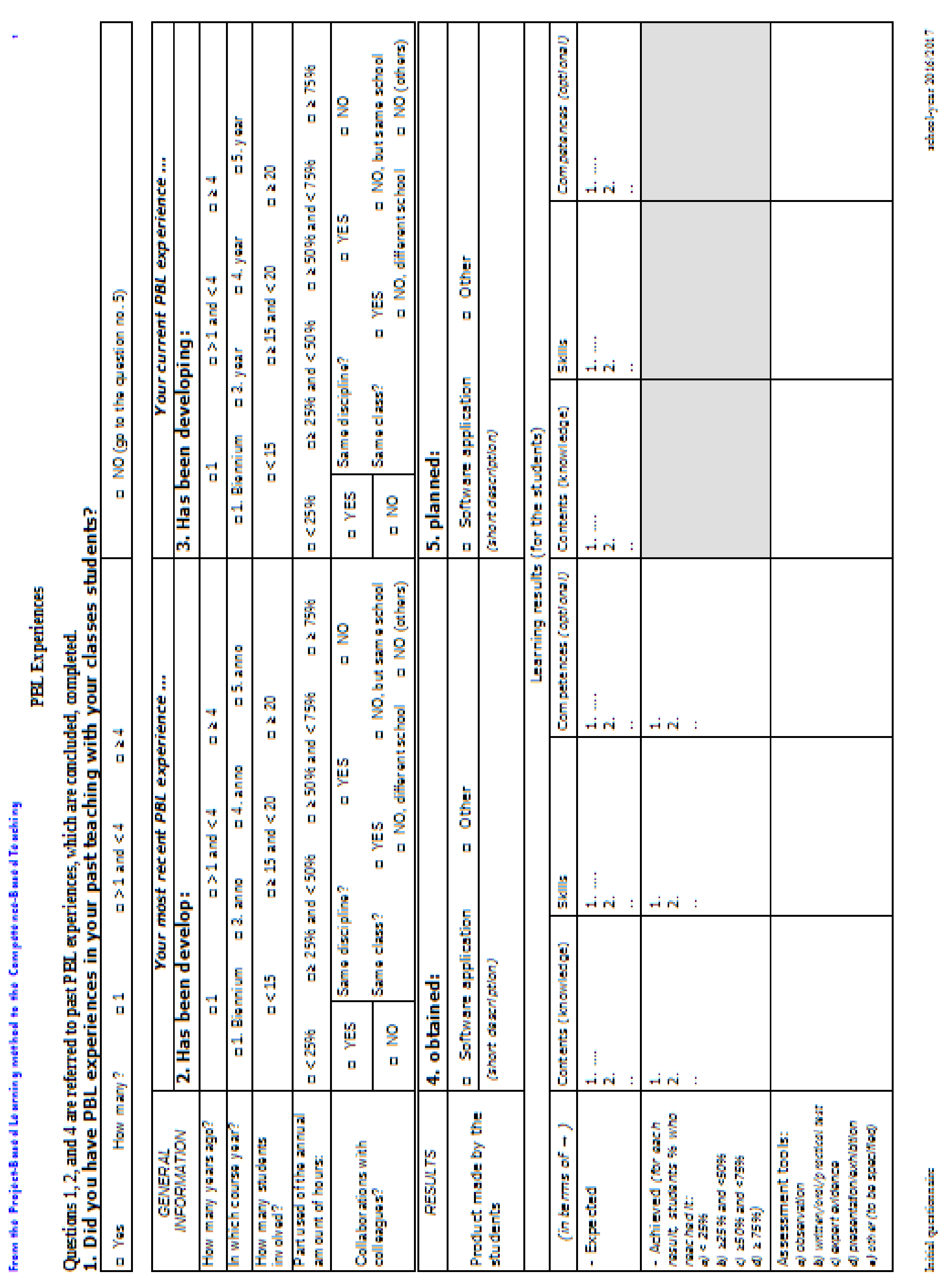
Skills:

(Note: Once you've completed this section, make sure you add all the assessment points to the project timeline)

Progetti e competenze per Informatica Action-Research Course – school year 2015/2016
Adapted by: Patton (2012) "Work that matters - The teacher's guide to project-based learning "

***Figure** F.2: PBL activity worksheet (page 2)*

G) PBL Experiences – Questionnaires



From the Project-Based Learning method to the Competence-Based Teaching

PBL Experiences

Questions 1, 2, and 4 are referred to past PBL experiences, which are concluded, completed.

1. Did you have PBL experiences in your past teaching with your classes students?

□ Yes How many? □ 1 □ > 1 and < 4 □ ≥ 4	□ NO (go to the question no. 5)

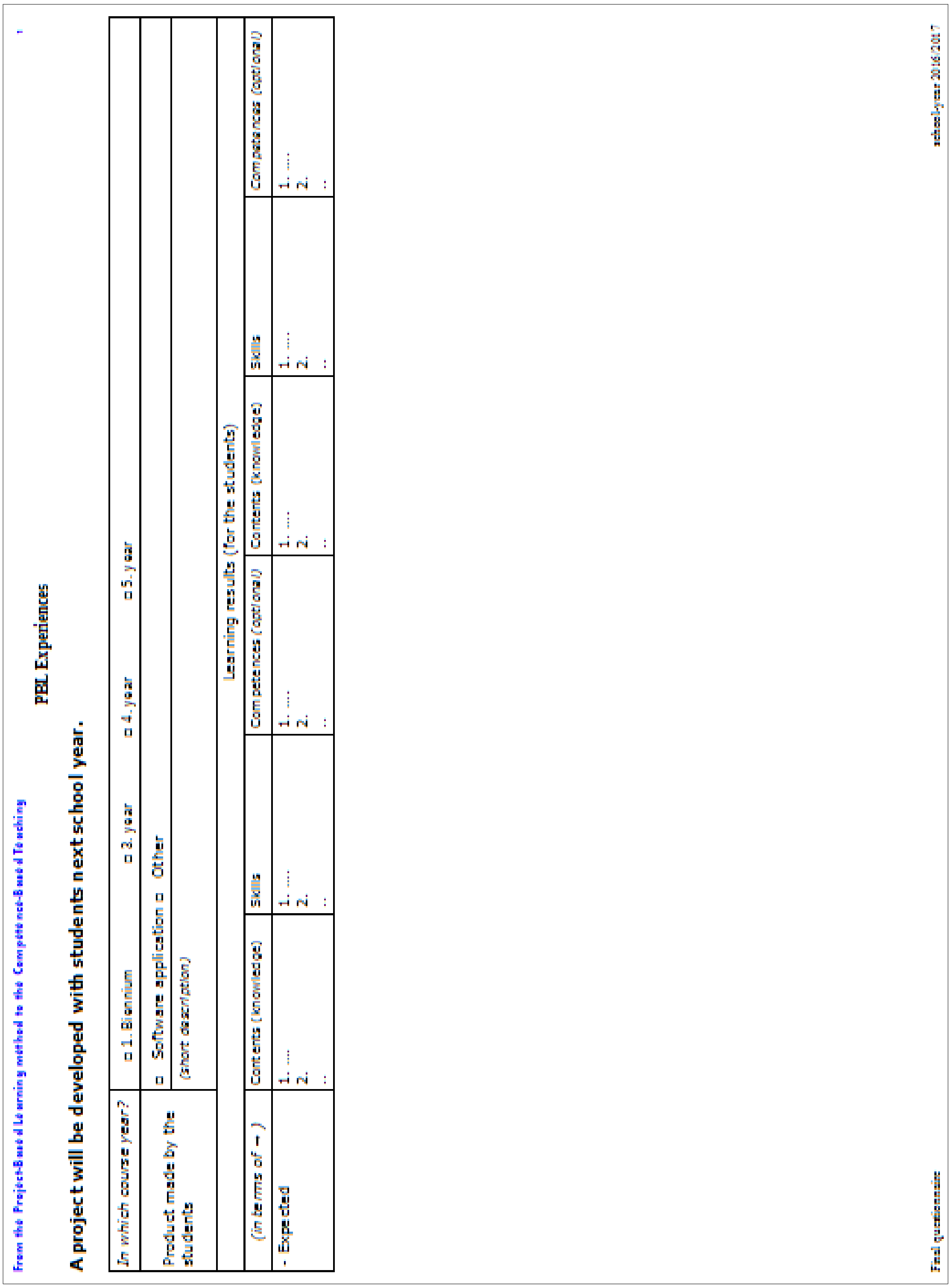
GENERAL INFORMATION	***Your most recent PBL experience …*** **2. Has been develop:**	***Your current PBL experience …*** **3. Has been developing:**
How many years ago?	□ 1 □ > 1 and < 4 □ ≥ 4	□ 1 □ > 1 and < 4 □ ≥ 4
In which course year?	□ 1. Biennium □ 3. anno □ 4. anno □ 5. anno	□ 1. Biennium □ 3. year □ 4. year □ 5. year
How many students involved?	□ < 15 □ ≥ 15 and < 20 □ ≥ 20	□ < 15 □ ≥ 15 and < 20 □ ≥ 20
Part used of the annual amount of hours:	□ < 25% □ ≥ 25% and < 50% □ ≥ 50% and < 75% □ ≥ 75%	□ < 25% □ ≥ 25% and < 50% □ ≥ 50% and < 75% □ ≥ 75%
Collaborations with colleagues?	□ YES: Same discipline? □ YES □ NO; Same class? □ YES □ NO, but same school □ NO, different school □ NO (others) □ NO	□ YES: Same discipline? □ YES □ NO; Same class? □ YES □ NO, but same school □ NO, different school □ NO (others) □ NO

RESULTS	**4. obtained:**	**5. planned:**
Product made by the students	□ Software application □ Other *(short description)*	□ Software application □ Other *(short description)*

Learning results (for the students)						
(in terms of →)	Contents (knowledge)	Skills	Competences *(optional)*	Contents (knowledge)	Skills	Competences *(optional)*
- Expected	1. …. 2. ..	1. …. 2. ..	1. …. 2. ..	1. …. 2. ..	1. …. 2. ..	1. …. 2. ..
- Achieved *(for each result, students % who reached it:* *a) < 25%* *b) ≥25% and <50%* *c) ≥50% and <75%* *d) ≥ 75%)*	1. 2. ..	1. 2. ..	1. 2. ..			
Assessment tools: *a) observation* *b) written/oral/practical test* *c) expert evidence* *d) presentation/exhibition* *e) other (to be specified)*						

Initial questionnaire school-year 2016/2017

Figure *G.1: PBL Experience – Past activities questionnaire*


From the Project-Based Learning method to the Competence-Based Teaching

PBL Experiences

A project will be developed with students next school year.

In which course year?	◻ 1. Biennium	◻ 3. year	◻ 4. year	◻ 5. year		
Product made by the students	◻ Software application ◻ Other *(short description)*					
Learning results (for the students)						
(in terms of →)	Contents (knowledge)	Skills	Competences *(optional)*	Contents (knowledge)	Skills	Competences *(optional)*
- Expected	1. .... 2. ..	1. .... 2. ..	1. .... 2. ..	1. .... 2. ..	1. .... 2. ..	1. .... 2. ..

Final questionnaire

school-year 2016/2017

Figure G.2: PBL Experience – Future activities questionnaire