INTRODUCTION

Every day we are struggling to understand the reality we live in. Sometimes we are able to unravel the mechanisms behind the things that happen around us, but more often we have to rely on parents, teachers or peers to come to a better understanding. Over many centuries our educational system has developed into a system in which the teacher plays a pivotal role. The teacher is the source of information and the student the receiver. In this exchange between student and teacher, there has always been a strong emphasis on the reproduction of knowledge. An early study by Stevens (1912) demonstrated that two-thirds of classroom questions required students to accurately recite textbook information. Sixty years later, Gall’s (1970) research still showed that 60% of the questions asked in the classroom required factual answers.

Even though teachers have always recognized the importance of actively involving students by asking them probing questions, research has observed that it was not until the 1960s that teachers’ role gradually changed (e.g., Bransford, Franks, Vye, & Sherwood, 1989). Instead of providing students with the question and the answer, teachers created more room for students to formulate and explore their answers to the posed question. This approach crystallized into a several teaching strategies that place an emphasis on the learner as an active agent in his or her learning process instead of the learner as a passive receiver of information. These instructional formats have been labeled student-centered and employ classroom practices such as observations, generating questions, discovering gaps in one’s knowledge base, and studying resources to try to overcome these gaps. Often they are also labeled as inquiry (or enquiry, in British English) based instruction.

In addition to being a teaching approach, inquiry also refers to the process of knowledge building within the learner or, in other words, the process of doing scientific investigations (Justice, Rice, Roy, Hudspith, & Jenkins, 2009; Olsen & Loucks-Horsley, 2000; Sandoval, 2005). Indeed, inquiry has been put forward as having the potential to strengthen the teaching-research nexus, although the type of inquiry learning one is involved in, is important in this respect (Spronken-Smith & Walker, 2010). Anderson (2007) has therefore made the distinction between inquiry learning, which refers to
engagement in the process of inquiry, and inquiry teaching, which comprises a whole spectrum of instructional techniques that make, to a varying degree, use of inquiry practices such as generating questions and formulating and evaluating explanations. This chapter will focus on the process of inquiry from a pedagogical perspective and will hence treat inquiry as a method to structure activities in the classroom (Sandoval, 2005). Inquiry-based learning, problem-based learning, project-based learning, and case-based learning are discussed.

It has been argued that inquiry is inherent to scientific research: “Beginning in the 17th century, when Galileo rolled balls down ramps, scientific research has been based on inquiry; experimental investigations that attempt to answer questions about the natural world” (Pine et al., 2006, p. 468). Generally stated, inquiry is thus based on a scientific investigation through classroom practices such as posing questions and it is aimed at knowledge acquisition and development (e.g., Blanchard, Southerland, & Granger, 2008). Instruction based on inquiry is most strongly advocated in science education by, for example, the National Research Council (NRC, 2000) and the American Association for the Advancement of Science (AAAS, 1993). Being a student-centered approach, it also originated as a reaction to the traditional classroom, believed to be too occupied with the teaching of facts (Schwab, 1962).

The prominent role given to inquiry at the policy level was prompted because it was believed to promote a deeper understanding of the subject matter as well as to facilitate transfer (i.e., the application of knowledge outside the classroom, Blanchard et al., 2008). In addition, it is argued that with inquiry, students learn the ins and outs of scientific processes and they gather an understanding of how these processes are related to each other (Singer, Marx, Krajcik, & Clay-Chambers, 2000; Spronken-Smith & Walker, 2010). Whether these claims can be supported by research findings will be discussed later in this chapter. First, a brief historical overview is given on student-centered learning, followed by a description of the constructivist view of learning, which is often associated with student-centered learning environments.

**HISTORICAL PERSPECTIVE ON STUDENT-CENTERED INSTRUCTION**

Educational methods that try to involve learners in their own learning processes can be found in the early history of didactics. The ancient Greeks used the *dialogos*, the method of the dialogue, in their education. In essence, a teacher proposes a problem and helps the learner solving this problem by asking questions. This method can be found in the work of Plato (427–347 B.C.) where he describes how Socrates helps a slave boy solving Pythagoras’ theorem (Plato, 1949). It was based on the assumption that the learner possessed all necessary knowledge, which just had to be activated. Further, the works of Socrates, Plato, and Aristotle (ranging from 470–320 B.C.) all include ideas about epistemology; the branch of philosophy that studies the nature and scope of knowledge.

The epistemology of more recent philosophers such as Immanuel Kant (late 18th to early 19th centuries) also stresses the role of the learner. Kant mentions the faculty of knowledge that people have, which refers to the influence of people’s own experiences in making sense of the environment around us. Therefore, he argues: “But though all our knowledge begins with experience, it does not follow that it all arises out of experience” (Kant, 1959, p. 25). Some form of mental activity is required from the one who experiences: People need to generate or construct knowledge on the basis of their individual experiences.
In the late 19th century, the American philosopher and educator John Dewey (1859–1952) reacted against passive teaching in a rote manner, which was common practice in the late 19th to early 20th centuries. He believed that a child is an active learner who learns best by doing. He argued for constructive activities in the classroom that were meaningful and interesting for children (i.e., connecting with the child’s social environment). Education should not be about becoming narrowly educated in academic topics; it should be pragmatic and should teach children how to think and adapt to a world outside (Dewey, 1902, 1929).

In sum, ascribing an active role to the learner is not a recently emerged idea in education. However, in recent years, it gained renewed attention in educational research because of the increased consideration of a learning view that starts from the idea that knowledge and understanding are actively constructed by the learner: constructivism (Birenbaum, 2003; Eberlein et al., 2008; Harris & Alexander, 1998; Tobias & Duffy, 2009).

### THE LEARNING VIEW RELATED TO INQUIRY: CONSTRUCTIVISM

Constructivist theories are concerned with how people make sense of situations or, more generally, with how people create meaning and construct knowledge out of experiences. A clear, unambiguous definition of constructivism is hard to find, but many writings in educational psychology (e.g., Mayer, 1996; Parsons, Lewis Hinson, & Sardo-Brown, 2001; Woolfolk, 2004) explain constructivism as a response to cognitivism, or more broadly, information processing theories. Cognitivism is a theoretical approach to understand the mind. This view argues that the teacher disseminates knowledge, which students absorb. The aim of instruction according to cognitivists is an increase of knowledge in students’ memory systems. Constructivism reacted against the traditional classroom that focused on the transmission of knowledge and a classroom in which teachers were the conveyors of meaning. Transferring knowledge from a knowledgeable person to someone who lacks specific knowledge does not work, according to a constructivist view of learning, since “wisdom cannot be told” (Bransford et al., 1989, p. 470). When constructivism is explained in terms of a reaction against cognitivism, it is seen as a theory of learning, concentrating on the question “How do learners acquire knowledge?” Although most cognitive views of learning agree with the concept of active learners, constructivism focuses more on learners constructing their own understanding. In this respect, constructivism could also be considered a rising paradigm in the field of cognitive psychology instead of a reaction against it (Duffy, 2009; Gijbels & Loyens, 2009; Sinatra & Mason, 2007).

Instruction based on inquiry is often related to constructivist views on learning because of the emphasis on classroom practices that involve active participation of the learner as well as a prominent role for questions and issues generated by the learner. However, caution is needed when instruction is labeled constructivist, because constructivism is situated on the prescriptive level in that case. Constructivism as a learning theory, on the other hand, is situated on the descriptive level (Mayer, 2009; Renkl, 2009). In other words, a theory of learning/knowing is then confused with a theory of pedagogy (Eggen & Kauchak, 2006). The question that arises in this respect is: What makes classroom practices constructivist? Bridging the gap between educational theory and practice is a challenge for all learning theories (Bednar, Cunningham, Duffy, & Perry, 1992; De Corte, 2000; Kennedy, 1997), but the many faces of constructivism have made it particularly difficult to narrow this gap.
Some educators believe that knowledge construction can occur, irrespective of instructional methods. By listening to a lecture, one can be involved in active attempts to construct new knowledge (Bransford, Brown, & Cocking, 2000). Von Glasersfeld (1993) argued that all mental activity is constructive because that is the way the mind operates. Even when learners are engaged in rote learning, they still are constructing knowledge. Therefore, all teaching can be considered constructivist (Windschitl, 2002). According to others, specific constructivist operationalizations can be identified in education, and they are typically student-centered.

As mentioned, instructional formats based on inquiry are examples of student-centered approaches to teaching. It is important to note that instruction based on inquiry is not by definition constructivist. It is, however, often related to and discussed within this framework, and it does carry several constructivist elements in it.

Constructivist Elements in Inquiry-Based Instruction

Although constructivism is an ill-defined concept with many flavors and colors and, although some researchers view it differently (e.g., Colliver, 2002), constructivist views on learning share some principles that can foster learning (e.g., Driscoll, 2005; Kantar, 2014; Marshall, 1992; Slavin, 2006).

First, the emphasis lies on the construction of knowledge, which forms the essence of constructivist views on learning. In this process, the learner tries to integrate new information with prior knowledge (Blumenfeld, 1992). Second, constructivists are of the opinion, although to a varying degree, that one can learn a lot from fellow students and that learning involves social negotiation (Savery & Duffy, 2001; Scardamalia & Bereiter, 1991). Communication of ideas about subject matter is believed to be facilitated by working together with fellow students, because of similar levels of understanding among them. Further, student discussions can serve as a gauge of prior knowledge and understanding (Slavin, 2006). Third, goal setting, plan making, and monitoring one’s learning process (i.e., self-regulated learning), are important foci of constructivist learning views. Self-regulated learning yields benefits for one’s learning (e.g., Boekaerts, 1999; Winne, 1995). Fourth, constructivist learning approaches use meaningful tasks in education to make learning situation more similar to future professional situations (Loyens, Rikers, & Schmidt, 2007).

These four elements—prior knowledge, social negotiation, self-regulation, and meaningful tasks—can be found in many instructional methods based on inquiry as discussed next. The challenge for constructivist and, in fact, for all views on learning is to apply the elements they describe in educational practice. A constructivist view brings the students, their interests, and previous experiences and knowledge to the fore, which has consequences for instruction.

INSTRUCTIONAL METHODS BASED ON INQUIRY

As mentioned earlier, inquiry comprises a broad range of educational approaches and formats that are student centered as opposed to teacher centered. Within these student-centered, inquiry approaches to teaching, we can identify considerable differences. According to Barrows (1986), three important variables can vary in different student-centered approaches: the design and format of the problem, project or case; the degree to which learning is teacher centered or learning centered; and the sequence in which problems or tasks are offered and information is acquired. Based on these
three dimensions, we will compare inquiry-based learning, problem-based learning, project-based learning, and case-based learning.

**Inquiry-Based Learning (IBL)**

In IBL, learning is propelled by the process of inquiry, which allows students to become familiar with particular subject matter that is introduced in the presented situation, but also to learn more about the inquiry process itself. Students are confronted with or generate themselves a question or puzzling situation that is open-ended to allow several responses or solutions (Savery, 2006). An example of a question in IBL is: In what ways does the moon’s shape and position in the sky change over the course of a month (Bell, Smetana, & Binns, 2005, p. 31)? The core elements of IBL have been described by the NRC (2000) and consist of engaging in scientifically oriented questions, seeking evidence to find answers to these questions, developing explanations/answers to the questions that were posed, evaluating these explanations as well as the probability of alternative explanations, and communicating and clarifying their own conclusions. In the example of the moon shapes, students can observe the moon during a month (Bell et al., 2005). Hence, questioning, critical thinking (i.e., students are forced to think about the data they have collected and try to understand their implications), problem-solving, and communication are important activities within IBL.

Windschitl, Thompson, and Braaten (2008) have proposed a cycle with the key intellectual activities in which students are engaged in IBL. The cycle starts with learners making an inventory of what is known and what they would like to know about the situation or phenomenon at hand. Next, students generate testable hypotheses for which they will seek evidence. In seeking evidence, many roads can lead to Rome. Finally, students construct an argument, which describes potential explanations and takes into account the evidence found. If needed, the cycle can be repeated, but eventually students will reach the goal of IBL: “to develop defensible explanations of the way the natural world works” (Windschitl et al., 2008, p. 955). More recently, Pedaste and colleagues (2015) reviewed 32 articles in their search for a synthesized inquiry cycle and identified five general inquiry phases: orientation, conceptualization (i.e., questioning and hypotheses generation), investigation (i.e., exploration or experimentation and data interpretation), conclusion, and discussion (i.e., reflection and communication). A student can take part in the IBL process as a group member, but can also individually be involved in the process, supported by fellow-students (Kahn & O’Rourke, 2005).

Whether instruction is inquiry-based depends on whether it starts with a research question that students need to investigate and answer by means of data analysis. This question can be generated by the students themselves (i.e., the most authentic form of inquiry as explained in the next paragraph), but an instructional approach can still be inquiry-based when research questions and data are already available to the students (Friedman et al., 2010). In that case, it is essential that students analyze the data themselves and construct their own arguments based on their analyses. Solely gathering information by searching literature resources or the Internet is not considered IBL (Bell et al., 2005).

The instructor’s role is primarily that of a facilitator of the inquiry process. Students can ask the instructor questions throughout the cycle. However, the role of the instructor varies depending on the amount of scaffolding that is needed and provided to the students. For example, with younger learners, the instructor has an important role in defining the boundaries of what will be studied. The instructor will choose a key
scientific phenomenon that can be explored, taking into account students’ interest. In addition to being central to science, this phenomenon needs to contain comprehensible underpinnings (Windschitl et al., 2008). Learners of this age are not yet ready to independently generate scientific questions and collect data. Ideally, the instructor helps students to progress to more autonomy in the inquiry process (Bell et al., 2005). Differences in the amount of guidance has led to the distinction of three subtypes of IBL: (a) \textit{structured inquiry} in which the question is given and the procedure to investigate is prescribed, (b) \textit{guided inquiry} in which the question is presented, but students have to work out themselves a procedure to answer the question, and (c) \textit{open inquiry}, also referred to as \textit{authentic inquiry}, in which the students also formulate topic-related questions themselves as well as coming up with possible procedures. The latter refers to the research scientists are involved in (Bell et al., 2005; Chinn & Malhorta, 2002; Colburn, 2000) and has been identified as providing the strongest link between teaching and research (Spronken-Smith & Walker, 2010). In sum, “as the level of scaffolding decreases, the independence of the students should increase” (Spronken-Smith & Walker, 2010, p. 726).

\textbf{Problem-Based Learning (PBL)}

In PBL, small groups of 10 to 12 students learn in the context of meaningful problems that describe observable phenomena or events (Barrows, 1996). It was first developed in medical education to show medical students the relevance of the subject matter by putting it in a realistic context (Barrows & Tamblyn, 1980; Schmidt, 1983). Therefore, the problems used in PBL often originate from professional practice. However, in other cases, PBL problems tackle problems or events typical for a particular domain of study (Barrows, 1996; Norman & Schmidt, 1992; Schmidt, Loyens, Van Gog, & Paas, 2007). In either case, the problems need to be understood in terms of their underlying theoretical explanations. Consider the following example of a problem from an educational psychology course (Loyens, Kirschner, & Paas, 2012):

You work as a school psychologist and your task is to diagnose children’s learning disorders, consult parents, and give them advice about possible treatments. On a Monday morning, you see Harry (7 years old) in your office. Harry seems an intelligent and spontaneous child. Harry’s teacher told you that Harry has no trouble understanding things. He is good at mathematics and does not seem to have any problems in social contacts, either at school or at home. An eye doctor has determined that Harry’s eyes are ok. Harry has great difficulty with learning to read. He often confuses the letters b and d, reverses words, and even writes some words backwards. The teacher told you that Harry has some trouble with his speech as well, but she could not give any specific examples.

After reading the problem, students discuss possible explanations for the problem. With respect to the problem example, students might come up with the diagnosis of dyslexia and subsequently will try to explain the different elements in the problem (e.g., language understanding, making contact, or the findings of an eye doctor) in the light of this diagnosis. They will talk about Harry’s possible problem(s), the signs and symptoms, and, most importantly, how he can be treated, because this was the school psychologist’s task. It is important to note in this respect that PBL students discuss the problem \textit{before} they have received any other curriculum input. The initial discussion of
the problem is meant to evaluate one’s prior knowledge about the topic (e.g., What do I know about dyslexia? Are alternative explanations possible for Harry’s symptoms?), as well as to discover one’s knowledge gaps (e.g., How can dyslexia be treated?).

This awareness of one’s knowledge gaps is believed to trigger interest in the subject matter that will motivate students to find out the state of affairs with respect to dyslexia. The issues that are still unclear after the initial discussion of the problem are formulated as questions, so-called learning issues (e.g., “What is dyslexia?” “What are possible treatments for dyslexia?”). The self-generation of learning issues is believed to create a perception of autonomy within students (e.g., Deci & Ryan, 2008), through which they experience agency. The learning issues direct students’ self-directed learning activities during the period of self-study in-between tutorial meetings. Students’ self-study activities consist of selecting relevant literature resources from such sources as the library, the electronic learning environment, or Internet, and studying them. The fact that students have a certain degree of freedom in selecting and studying the literature resources adds to the experience of autonomy and agency as well. During the next tutorial meeting, students share their findings with each other and critically evaluate the answers to the learning issues (Barrows, 1996; Hmelo-Silver, 2004; Schmidt, 1983). Tutorial meetings last for two or three hours and are held once or twice a week (Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009).

Tutorial meetings in PBL are guided by a tutor who stimulates the discussion, provides students (if necessary) with just-in-time content information, evaluates the progress, and monitors the extent to which each group member contributes to the group’s work (Schmidt et al., 2007). A tutor can be an instructor or a senior student and guides both the PBL process and students’ learning (Hmelo-Silver & Barrows, 2006).

In addition to via the tutor, guidance is also provided in PBL through the problems and the sequence in which they are presented to the students. The problem example about dyslexia is presented to first-year psychology students, after they have studied the topic of learning to read. In this way it can build on students’ prior knowledge, since they first learned the normal development of learning to read before tackling specific problems in the reading process (Loyens et al., 2012).

Not surprisingly, also within PBL, different formats can be distinguished. Unlike IBL, those formats do not differ in the amount of guidance that is offered, but in the aimed outcome of PBL. Based on the outcome, three different types of PBL can be distinguished: a type that stresses the construction of flexible knowledge bases (Type 1), a type that emphasizes the development of inquiry skills (Type 2), and a type that perceives PBL primarily as a tool for ‘learning how to learn’ (Type 3; Schmidt et al., 2009). The Type 1 PBL accounts for the most PBL curricula and is most often researched.

Project-Based Learning (PjBL)

In Project-Based Learning or Project-Centered Learning (often also abbreviated to PBL, but to avoid confusion with problem-based learning, PjBL is used), the learning process is organized around projects, which drive students’ activities (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). Students learn central concepts and principles of a discipline through the projects. Therefore, projects are central in PjBL or, in other words, “projects are the curriculum” (Thomas, 2000, p. 3). In general, students have a significant voice in selecting the content areas and nature of the projects they do, although not necessarily. In any case, students have a significant degree of control of the project they will work on and what they will do in the project. The
projects are hence student-driven and, similar to PBL, try to create agency within learners. Specific end products need to be reached and those are clearly defined, while the processes to get to the end product can vary. The end products (e.g., a computer animation, thesis, website, presentation, report) serve as the basis for discussion, feedback, and revision (Blumenfeld et al., 1991; David, 2008; Helle, Tynjälä, & Olkinuora, 2006; Tal, Krajcik, & Blumenfeld, 2006). They are believed to reflect a learner’s knowledge in information search, knowledge related to the project’s topic, and metacognitive knowledge (i.e., knowledge about one’s own cognition, Grant & Branch, 2005). A project can be a problem to solve (e.g., How can we reduce the pollution in the schoolyard pond?), a phenomenon to investigate (e.g., Why do you stay on your skateboard?), a model to design (e.g., Create a scale model of an ideal high school) or a decision to make (e.g., Should the school board vote to build a new school? Yetkiner, Anderoglu, & Capraro, 2008). Contextualization is crucial in this respect; projects are designed to be realistic and meaningful for students (Helle et al., 2006; Thomas, 2000). Students engage in different activities while working on the project, such as problem-solving, design, decision making, argumentation, using and weighing different pieces of knowledge, explanation, investigation, and modeling (Krajcik, McNeill, & Reiser, 2007; Thomas, 2000). Students can work individually or together and projects last for considerable periods of time (Helle et al., 2006; Thomas, 2000).

The role of the instructor consists of facilitating the project. That is, the instructor helps with framing and structuring the projects, monitors the development of the end product, and assesses what students have learned (David, 2008; Helle et al., 2006).

**Case-Based Learning (CBL)**

CBL is a form of collaborative learning where learners are presented with a case. For example, in a teacher education course, students can be presented with a case on classroom management in which the teacher wants to change the arrangement of children’s desks because two boys are constantly talking and interrupting the class instruction. However, one of the two boys seems to have few friends and is experiencing problems adjusting to school, and the boy next to him seems to be the only one he is close with (Choi & Lee, 2009, p. 104). Cases are similar to problems in PBL. However, in Barrows’ terms (1986), the sequence of the problem and gathered information is different. In PBL, the problem is the starting point. In CBL, students need to prepare in advance for the group session and can ask questions during the session, when the case is discussed under the guidance of a facilitator (Srinivasan, Wilkes, Stevenson, Nguyen, & Slavin, 2007; Williams, 2005). Therefore, CBL can be considered as a special form of PBL. Both PBL and CBL also share a focus on acquiring new knowledge (Aditomo, Goodyear, Bliuc, & Ellis, 2013).

**Differences Between IBL, PBL, PjBL, and CBL**

All instructional formats just described carry the constructivist elements that were mentioned earlier. They all are based on the idea that students need to be actively engaged in the subject matter by investigations and discussions. Therefore, students construct knowledge in an active way. Although IBL and PjBL can also be carried out individually, all formats usually imply working together with fellow-students. Next, all methods require student control and students taking responsibility for their learning process. Students need to plan activities, monitor progress, and evaluate at regular
times. Finally, all inquiry-based instructions work with meaningful tasks, whether they are questions, problems, projects or cases. Learning activities are therefore put in a realistic context for students.

Despite this common ground, the methods do differ from each other on one or multiple aspects. The difference between IBL on the one hand and PBL and CBL on the other hand lies in the role of the teacher. In PBL and CBL, the teacher’s (i.e., tutor’s) task is to facilitate the group discussion. While this is also true for IBL, here the teacher also acts as the expert, because (s)he provides information to the students based on their questions. In PBL and CBL, students have to rely more on themselves to find information about the problem themselves (Savery, 2006). In addition, the range of learning activities is usually more diverse in IBL and PjBL compared to PBL and CBL. For example, students may be asked to reflect on the question or puzzling situation or identify research questions, but can also be asked to interview persons or visit specific locations related to task (Feletti, 1993). In addition to more diverse learning activities, IBL and PjBL also have more diverse end products compared to PBL and CBL. Depending on the amount of guidance given, IBL and PjBL can be more student-centered compared to PBL and CBL, since in some occasions students come up with their own questions and projects. As noted, the difference between PBL and CBL lies in the moment the discussion of the problem or case takes place. In PBL, this is before any other curriculum input, while in CBL students need to be prepared when they come to the group session (Srinivasan et al., 2007; Williams, 2005).

A Note: Discovery Learning

An instructional format that is not discussed in this chapter is discovery learning. Discovery learning, advocated by Bruner (1961), can be seen as a very open form of inquiry-based instruction. It is a learning format in which students work on examples presented by the teacher, in order to discover the relations among the examples and to formulate general principles that apply to them. These inductive reasoning activities are said to trigger students’ curiosity and make students persistent to find answers. In addition, the conceptions learned through discovery learning were believed to be better remembered (Bruner, 1961). However, it has been argued that inquiry-learning and discovery should not be lumped together, because inquiry implies more activities than solely discovery (Edelson, Gordin, & Pea, 1999). In addition, inquiry implies more guidance compared to pure discovery learning. Although more guided forms of discovery exist as well, discovery in its pure form should be considered different from inquiry-based instruction. Indeed, a recent meta-analysis on discovery learning revealed that unassisted discovery learning (e.g., teaching oneself, completing practice problems, conducting simulations) does not benefit learners, while forms of assisted discovery (i.e., some form of instructional guidance/scaffolding or regular feedback to assist the learner at each stage of the learning tasks) can be beneficial for students’ learning (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011).

Apples and Oranges

As a final note in this section, it is important to acknowledge that, apart from the fact that there are several forms of student-centered learning using different labels (i.e., IBL, PBL, PjBL, and CBL) differences may also exist within these separate approaches. Different types of IBL and PBL were already indicated. Differences within each approach
exist primarily in terms of implementation and focused elements (Lloyd-Jones, Mar
getson, & Bligh, 1998). This can be ascribed to various reasons such as modifications
due to the target group (e.g., K–12 versus higher education), but also due to the so-
called coverage virus; the fear of teachers that subject-matter is insufficiently covered,
leading to the incorporation of more teacher-centered practices and less student
autonomy (Moust, Van Berkel, & Schmidt, 2005). Also, disciplinary variations exist
(Aditomo et al., 2013) and hybrid forms have emerged throughout the years, combi-
ning student-centered with teacher-led formats (e.g., Kwan, 2008).
Whatever method used, conceptual clarity and a clear description of the elements
constituting a particular method are indispensable. For example, in the PBL context,
Lloyd-Jones and colleagues (1998, p. 494) argued: “For the purposes of research, eval-
uation and educational development the brevity of the “PBL” label is an inadequate
description.” Fair comparisons with traditional, teacher-centered methods can only
follow out of careful descriptions and explanations of the method under study. Even
with clear descriptions, examining the effectiveness of multifaceted approaches is
challenging (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003). For example, Woods
(2014) identified no less than 32 learning environments that all start with a problem,
empower students with parts if not all of the learning process, mostly include extensive
peer interaction, and all have students actively engaged. Therefore, some researchers
have even considered it impossible to compare inquiry methods with direct instruc-
tion, as reflected in this quote of Jonassen (2009, p. 29):

I am not able to identify “high-quality research studies comparing the effective-
ness of inquiry methods and direct instruction” because it probably does not exist
and cannot exist. Researchers examining the effectiveness of direct instruction begin
with fundamentally different assumptions, evoke significantly different theory bases,
and use different research methods than researchers examining informal or inquiry
learning. Therefore the questions they ask, the learning outcomes they seek and the
research tools and methods they use are also quite different. We cannot compare
apples with oranges. Each relies on intellectual biases that would leave the other at a
disadvantage were we to compare results.

Although direct comparisons between inquiry-based instruction and direct instruc-
tion might not always be possible or reported in the research literature, the next section
gives an overview of empirical studies on the different forms of inquiry-based instruc-
tion. Nevertheless, we do reckon with the caveats just mentioned.

A REVIEW OF THE RESEARCH OF INSTRUCTION BASED ON INQUIRY

Generally, research on instructional methods based on inquiry can be divided into
categories. First, several studies describe students’ and teacher’ perceptions of
a specific method and their experiences with working with it. Although valuable for
those who plan to implement a specific method, this line of research is mainly explora-
tory and descriptive. Therefore, these studies do not give a decisive answer about
the effectiveness of the method under investigation. However, a great deal of studies
conducted in the field of inquiry-based instruction could be categorized here (Justice
et al., 2009; Helle et al., 2006; Park Rogers & Abell, 2008).
A second line of research investigates specific elements of an inquiry-based method
of instruction. For example, one might manipulate the size of the tutorial group in
PBL in an experimental study to discover the ideal group size. Similarly, one can vary end products in PjBL to determine whether these variations lead to different ways of dealing with the project. In a way, this second line of studies searches for improvements in the existing methods by scrutinizing their constituting elements. Here, effectiveness should be considered in the light of the specific element under investigation, not in terms of the method as a whole.

Finally, the third line of research investigates the effectiveness of an instructional method as a whole. Often, a comparative approach is used, contrasting a student-centered format with a control group or investigating changes before and after a curriculum shift. Certainly, great disparities of outcome variables exist, because one can argue about the question: “What makes an instructional method effective?” Usually, effectiveness is measured in terms of knowledge (i.e., student performance on knowledge tests), skills/competencies, and/or affective variables such as motivation. Effects on student satisfaction should be more considered as an example of the first line of research. The research review presented in this chapter is focused on this third line of research. Thus, for articles in which both self-reported ratings and non-self-report learning outcomes were investigated only the findings that were not based on self-report measures were included, because the self-report data can be seen as an instance of the first line of research. Further, we focused on knowledge and skills in this review, since those are often considered most revealing in terms of effectiveness. However, we do acknowledge that effects on affective variables can be insightful as well (e.g., Litmanen, Lonka, Inkinen, Lipponen, & Hakkakainen, 2012).

In our search for research articles investigating inquiry methods, we employed several criteria. First, investigation of the instructional method needed to be the focus of the article. Studies investigating variables solely within an inquiry-based environment, but not dealing with the learning environment in itself were not included. Second, we limited our search to studies that have been published during the past five years (i.e., 2010–2015) because we intended to give a state-of-the-art review.

Several literature searches in Web of Science were carried out using the terms inquiry, inquiry-based, problem-based, project-based, and case-based (with and without hyphen). Only empirical and review articles in peer-reviewed journals and edited books that were published in the English language and available in full text were considered.

**Research on the Effects of IBL**

In 2012, a meta-analysis was published on the effects of inquiry-based reforms on student learning of science in the 10 years (1996–2006) immediately following the publication of the *National Science Education Standards* (NRC, 1996). An overall mean effect size of 0.50 (SD = 0.56) was found based on the 22 studies included (Furtak, Seidel, Iverson, & Briggs, 2012). In a similar vein, Wang and colleagues (2011) conducted a meta-analysis on the effects of inquiry-based instruction on Taiwanese elementary and middle school children’s learning outcomes (i.e., conceptual understanding and scientific process skills) for science. Articles were selected from the time period 1997–2009 and results demonstrated a positive weighted mean effect size in favor of IBL compared to traditional teaching. Our search from 2010 till 2015 generated three additional articles that investigated the effects of IBL, which will be outlined below.

Harris and Tweed (2010) report geography students’ grades before and after the implementation of an inquiry-based module on glacial processes, landforms, and
landscapes. They found a slight increase from an average 57% score for the module in the two academic years prior to the inquiry-based module implementation, while students’ scores after the implementation were, on average, 60%. However, given the small number of students in the modules (i.e., 9 to 15), it could not be determined whether this increase was statistically significant.

Madden (2010) investigated the effects of the implementation of IBL in a “history of economic thought” course. A pre-posttest design was used with respect to students’ contributions to a class discussion, making use of IBL. A statistically significant increase was observed between the pre- and post-discussion median scores. The author concluded that a well-structured inquiry-based discussion can positively impact learning.

Finally, Simsek and Kabapinar (2010) investigated the effects of an 8-week IBL intervention in a fifth-grade science class. During the intervention, students worked in small groups where they were encouraged to share their ideas with their classmates, discuss their observations and interpret findings of the experiments carried out. A pre-posttest design was used to measure the children’s conceptual understanding (i.e., a test consisting of 38 multiple choice questions) and scientific process skills (i.e., a test consisting of 31 multiple choice questions). Children’s scores on both tests significantly increased from pre- to posttest. However, no effect sizes were reported.

In sum, effect studies show overall positive results IBL, although a lack of control groups makes it difficult to draw definite conclusions.

**Research on the Effects of PBL**

For PBL, a recent review of PBL effect studies (Loyens et al., 2012) included studies published from 2004 to 2010 that investigated the effects of PBL on knowledge, skills, and competencies. Furthermore, articles that studied the PBL curriculum as a whole were included. These articles did not study the effects of PBL on knowledge or skills, but compared PBL and traditional, lecture-based curricula in terms of graduation rates and study duration as a measure of how successful a particular curriculum was. For PBL’s effects on knowledge it could be concluded that the results were mixed: some studies found effects, although small, and others failed to find effects. No negative effects were reported either. These results were in line with an earlier meta-analysis of curricular comparisons, using a single PBL medical school in the Netherlands. The overall weighted effect size averaged over the 90 comparisons involving the PBL curriculum under study and various Dutch medical schools was equal to $d = 0.07$ (Schmidt et al., 2009), which is considered less than even a small effect. However, it has been argued that curriculum comparison studies are at best quasi-experimental, so they are prone to forms of selection bias. Therefore, Schmidt, Muijtjens, Van der Vleuten, and Norman (2012) reanalyzed the data from the Schmidt et al. study of 2009 and controlled for two potential biases: differential student attrition (because graduation rates are higher in PBL compared to traditional curricula, see below) and differential exposure (because study duration is shorter in PBL compared to traditional curricula, see below). The reanalysis demonstrated medium-level effect sizes favoring PBL curricula. After corrections for attrition and study duration, the mean effect size for knowledge acquisition was 0.31 and for diagnostic reasoning was 0.51 (Schmidt et al., 2012).

For skills, it seemed warranted to conclude that PBL graduates have some advantages in social skills compared to graduates from a traditional curriculum. There is some evidence for beneficial effects of PBL students in medical curricula on medical skills compared to medical students in traditional curricula, although not all studies endorse
this. For critical thinking skills, the conclusion seemed positive. However, a remark on this conclusion is the limited number of studies in this area. With respect to graduation and retention rates and students’ study progress, all studies indicated positive effects for PBL curricula (Loyens et al., 2012).

PBL seems to have been popular for curriculum comparisons, because our literature search from 2010 till 2015 generated 17 additional articles that investigated the effects of PBL. A recent systematic review and meta-analysis by Zhang and colleagues (2015) on the effectiveness in PBL in Chinese undergraduate medical education showed that compared to lecture-based formats, students in PBL obtained significantly higher examination scores (standardized mean difference—SMD = 0.82; 95% confidence interval—CI [0.63, 1.01]). It is concluded that this finding is inconsistent with several previous studies indicating that PBL students either perform no differently or slightly worse than students in conventional on measures of knowledge such as basic sciences examinations (see for an overview: Strobel & Van Barneveld, 2009). According to Ding and colleagues (2014), PBL is also increasingly popular among preventive medicine educators in China. They selected 15 studies in this area and conducted a pooled analysis to obtain an overall estimate of the effectiveness of PBL on learning outcomes of preventive medicine students. Overall, PBL was associated with a significant increase in students’ theoretical examination scores (SMD = 0.62; 95% CI [0.41, 0.83]) than LBL. For the skill-based outcomes, the pooled PBL effects were also significant for problem solving skills (odds ratio—OR = 4.80; 95% CI [2.01, 11.46]), self-directed learning skills (OR = 5.81; 95% CI [3.11, 10.85]), and collaborative learning skills (OR = 4.21; 95% CI [0.96, 18.45]; Ding et al., 2014). While widespread in preventive medicine in China, PBL is still in its infancy in Chinese dental education. A meta-analysis by Huang, Zheng, Li, Li, and Yu (2013) included 11 articles in which PBL was compared to traditional teaching methods. Theoretical/knowledge scores, practical/skills scores, and pass rates were investigated. Results showed positive effects in favor of PBL for knowledge (SMD = 0.88; 95% CI [0.46, 1.31], p < 0.01) and skills scores (SMD = 1.48; 95% CI [0.95, 2.00], p < 0.01). However, the pooled result did not show any positive effect on higher pass rates for PBL (risk ratio—RR = 1.06, 95% CI = 0.97–1.16, p = 0.21).

A quasi experimental study with a control group posttest only design was conducted to investigate the effects of PBL on upper secondary school Malaysian students’ mathematics performance. The experiment was carried out for six weeks and the PBL group was characterized by opportunities to learn mathematical processes associated with communication, representation, modeling, and reasoning, as opposed to the traditional (control) group that had a strong focus on exercises, rules, and equations that needed to be learned. Results demonstrated that the PBL group (M = 67.38, SD = 19.75) performed better in the overall mathematics performance (i.e., learning assessments on mathematical concepts and skills learnt in the topic statistics) than the control group (M = 60.58, SD = 17.90), but this difference was not statistically significant (F =1.46, p > 0.05; Abdullah, Tarmizi, & Abu, 2010).

Baturay and Bay (2010) compared an online PBL “Introduction to computers” course in higher education with an online control group. All students were taught with the same web-based content, assessed by the same rubric, and guided by the same instructor. The intervention included the following characteristics: (a) problems to stimulate or focus learning, (b) an instructor who coached the students and facilitated their progress by supporting their learning, (c) asynchronous discussion boards to facilitate student interaction and cooperative learning, (d) students who were supposed to self-direct themselves to achieve their individual learning objectives. It was
scrutinized whether a significant change in the students’ pre- and posttest scores after participating in the online PBL intervention could be observed along with a significant difference in the achievement scores for experimental and control group students. The same test (i.e., 40 multiple choice questions) was applied as a pre- and post-test prior to and after PBL intervention to both the experimental and control groups. Students’ online midterm and face-to-face final exam scores were recorded to measure both groups’ course performances. Results showed there was a significant difference in the pre- and post-test scores of the PBL group, while this was not the case for the control group. However, both groups did not differ in their midterm and final examination scores.

Another study looked at outcomes of a PBL intervention for postgraduate students taking an educational statistics course, using a pre-posttest design. The PBL intervention consisted of collaborative activities for students and for each topic covered in the course, students started with a problem scenario. In processing and understanding the problem scenario, students were given guided questions that needed to be answered in the given order. Students were also encouraged to source information on the website and any textbooks suggested for the course and to use multiple resources when answering the questions. A pretest was administered after four weeks of conventional learning, a posttest five weeks after the shift to PBL, and a delayed posttest after another five weeks of PBL. Comparison of students’ performance based on the three tests showed that there was significant difference between mean performance, $F(2,28) = 5.571$, $p < 0.05$, but only between the pretest and the delayed posttest, $t(30) = 3.68$, $p < 0.05$, not between the pretest and the posttest (i.e., after five weeks), nor between the posttest and delayed posttest (Tarmizi & Bayat, 2010).

A study in the field of physics compared a PBL (i.e., working around a problem scenario) and a traditional-teaching control group on retention of physics knowledge and problem-solving strategies. To that end, two tests (i.e., one measuring retention of knowledge and one measuring problem-solving strategies) were administered four times to both groups of students: directly after the course (i.e., exam) and 3, 6, and 12 months after the course. Directly after the course, the PBL group outperformed the lecture group on all questions of the exam and this picture remained after 3 (PBL: 61.7% versus control: 29.5% correct answers), 6 (PBL: 53.2% versus control: 27.5% correct answers) and 12 (PBL: 50.7% versus control: 24.7% correct answers) months. Results were similar with respect to problem-solving abilities, where a significant increase in the ability to solve physics problems could be observed, which was maintained long after the instruction was over (Becerra-Labra, Gras-Marti, & Torregrosa, 2011).

Also in the domain of physics, Celik, Onder, and Silay (2011) investigated student teachers’ physics knowledge (by means of a physics exam) across two groups: a PBL and a lecture-based group. While at the pretest, no significant differences were found between both groups, after the three sessions of the intervention, the PBL group ($M = 78.85, SD = 11.25$) significantly outperformed the LBL group ($M = 61.45, SD = 17.61$), $t(42) = 3.81$, $p < 0.05$. 

Similarly, college students enrolled in an elementary physics course participated in 7 hours of instruction on two physics concepts, one (i.e., electromagnetic field) via a PBL method (consisting of a session on problem representation, a collaborative learning activity, and a session on problem resolution) and the other (i.e., gravitational field) via a lecture/discussion method. A comparison class enrolled in the same course with the same instructor underwent the identical experience except that matching of
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Concept and method was reversed (i.e., crossed within-subjects design). Both comprehension as well as integration and application measurements were administered twice (a first assessment after 2–4 weeks and a second one after 9 weeks). On both concepts (i.e., electromagnetic field and gravitational field), the majority of students performed better on the concept learned via PBL than the concept learned via lecture/discussion and this effect was sustained over time. Consistently, students in both classes integrated and applied better the content learned via PBL for both concepts, and this effect was also maintained over time (Pease & Kuhn, 2011).

Another controlled experiment of PBL was conducted in a middle school. Between- and within-subject comparisons were made of social studies students learning the same material (i.e., groupthink and learning and memory) under three instructional conditions: lecture/discussion, characteristic small-group PBL, and solitary PBL. In the solitary PBL group, students worked alone and did not engage in talk with classmates. They were presented with the problem and spent their time working quietly on it, while the coaches answered occasional questions if students raised their hands. Assessments of comprehension (i.e., explaining concepts) and application of concepts in a new context 9 weeks after instruction showed superior mastery in both PBL conditions, relative to the lecture condition, and equivalent performance in the two PBL conditions (Wirkala & Kuhn, 2011).

Conceptual understanding of Newtonian mechanics was the topic of investigation in a study by Sahin (2010). Turkish university students were enrolled in a calculus-based introductory physics class of which almost half was taught according to the PBL method, which implied the discussion of real-life problems, constructed in the form of a scenario-like context, by groups of eight students. A teaching assistant or faculty member guided each group. The problem-solving process took place in PBL sessions until the students reached and agreed upon a solution to the given problem. The other half of the participants in this study received traditional instruction (i.e., traditional lectures and recitations). A pre- and posttest of the Force Concept Inventory was administered. Although both groups’ conceptual understanding scores improved from the pre- to post-administration, the improvement was significantly higher for the PBL group (pre: \( M = 56.29, \ SD = 10.84 \); post: \( M = 70.71, \ SD = 14.00 \)) than it was for the traditional group (pre: \( M = 45.83, \ SD = 16.41 \); post: \( M = 56.01, \ SD = 16.17 \)).

Tatar and Oktay (2011) examined the effectiveness of PBL on student science teachers’ understanding of the first law of thermodynamics and their science process skills. Third-grade university students were pre- and posttested on an achievement test and the Science Process Skill Test. Statistically significant differences emerged between students’ average pre- \( (M = 34.72) \) and post-achievement \( (M = 74.08) \) test scores, \( t(47) = 19.57, p < 0.05 \). The same picture was seen for science process skills: significant pre- \( (M = 25.31) \) to posttest \( (M = 27.17) \) gains, \( t(47) = 3.60, p < 0.05 \).

In the field of chemistry, freshmen of a Turkish university who took a general chemistry course were randomly assigned to a PBL and a lecture-based control group (Tosun & Taskeseniligil, 2013). During five weeks, students learned about solutions and their physical properties in either a PBL (i.e., problem scenario, definition of learning issues, brainstorming and information gathering outside the class, preparing a report for presentation in class) or a lecture-based (i.e., lecturing, in-class discussions, note taking, and asking questions when they had difficulty in understanding) format. An achievement test as well as the Scientific Processing Skill Test were applied as pre- and posttests. While no statistically significant differences emerged on the achievement pretest between both groups, this was the case for the posttest, with the PBL group
obtaining higher scores, \( F(1, 70) = 20.450; p < 0.05; \eta^2 = 0.231 \). The same results could be observed in favor of PBL regarding scientific processing skills, \( F(1, 67) = 4.451; p < 0.05; \eta^2 = 0.064 \).

A comparison among a PBL, lecture-based, and self-study group that served as a control group was made in a study by Wijnen, Loyens, and Schaap (in press). Effects on knowledge acquisition and retention on the topic of learning approaches and constructivism were tested in a controlled experiment in a lab setting. The PBL session took place in three phases: 1) a prediscussion in which the problem was introduced and discussed based on prior knowledge and common sense. Learning issues are collaboratively formulated; 2) a self-study phase in which students individually search for and study literature resources to answer the learning issues; and 3) a reporting phase in which the answers to the learning issues are discussed in the group (Loyens et al., 2012). The lecture-based group received a lecture on different learning approaches and constructivism and the self-study group studied a text about the topic at-hand. However, in order to ensure the same learning materials in all three conditions, the PBL and lecture-based group also had the opportunity to study the same text after the instruction. Knowledge acquisition was tested on both an immediate posttest and a delayed posttest, one week later. Results showed beneficial effects for the PBL group on the immediate and the delayed test compared to the lecture group. There were no differences between knowledge acquisition scores for the self-study condition and either of the other conditions. Moreover, no differences on knowledge retention were shown, because the decline in performance over time was equal in all conditions.

Three studies investigated PBL’s effectiveness in nursing education. In their meta-analysis, Shin and Kim (2013) examined the contents of 22 articles (from 1972 till 2012) that addressed the effects of PBL in nursing education. Overall, using a random effects model, an effect size of 0.70 was found, which reflects a medium-to-large effect. A systematic review and meta-analysis was also performed specifically for nursing students’ critical thinking skills in PBL (Kong, Qin, Zhou, Mou, & Gao, 2014). Nine articles representing eight randomized controlled trials were included in the meta-analysis. Most studies were of low risk of bias. The pooled effect size showed problem-based learning was able to improve nursing students’ critical thinking (overall critical thinking scores: \( SMD = 0.33, 95\% CI [0.13, 0.52], p < 0.01 \)), compared with traditional lectures. However, differences in the measurement instruments could be observed: while subscales of the California Critical Thinking Dispositions Inventory (CCTDI) and Bloom’s Taxonomy favored PBL, effect sizes for all subscales of the California Critical Thinking Skills Test (CCTST) and most subscales of the Watson–Glaser Critical Thinking Appraisal (WCGTA) were inconclusive.

Lastly, Khatiban and Sangestani (2014) assigned Iranian nursing students in two groups: a PBL and a non-PBL control group. Among other variables, they tested students on their knowledge and skills in applying the so-called Nursing Process (i.e., assessment, diagnosis, planning, intervention, and evaluation). Participants were asked to write such a Nursing Process for his/her allocated patient on the last day of the clinical training and these reports were rated by a master lecturer (out of the research) blind to the student groups according to a checklist. PBL students outperformed the non-PBL group (\( z = 4.61, df = 68, p < 0.001 \)).

In sum, given the high number of recent articles investigating the effects of PBL, it can be concluded that PBL is still a popular instructional method in education. Overall, effects seem to be positive.
Research on the Effects of PjBL

A recent meta-analysis of Ayaz and Söylemez (2015) investigated the effects of PjBL on students’ achievement in science classes in Turkey. 41 studies were included and results demonstrated, using a random effects model, that PjBL was more effective than traditional instructional methods ($ES = 0.997, 95\% CI [0.777, 1.218]$, which can be considered moderate. The authors also looked into the highest effect sizes and they were observed for PjBL in high school ($ES = 1.536$), in physics ($ES = 1.046$), and between 1–20 lesson hours ($ES = 1.203$).

Koh, Herring, and Hew (2010) compared graduate students’ online postings in a course that comprised both project-based and non-project learning activities on knowledge construction using computer-mediated discourse analysis. Chi-square analyses revealed that students’ online discussions during PjBL were characterized by more advanced levels of knowledge construction ($\chi^2 (4, N = 184) = 17.7, p < 0.01$, Cramer’s $V = 0.31$). This effect in favor of PjBL was caused by a better integration of ideas. On all other defined levels of knowledge construction (i.e., sharing information, triggering events, exploration, and resolution of ideas), no differences were found. In contrast, students’ online postings outside project-based learning rarely moved beyond the lower levels of information sharing and idea exploration.

Uyangör (2012) used a single group pre-posttest design to test the effects of PjBL in a polygon and plane geometry unit on ninth-grade students’ performance. The test was designed by the researcher and was based on the secondary education geometry lesson education and was pilot tested first. The intervention took four weeks and consisted of the introduction of multidisciplinary problem/scenario on which students work in small groups. Students are engaged in thinking, problem solution, creativity, access to information, processing of information, and compromising on the newly learned information. Results demonstrated a statistically significant increase from students’ pre- to posttest (mean difference = 37.68, $SD = 31$, $t = 2.095$, $p < 0.05$).

Finally, Bilgin, Karakuyu, and Ay (2015) compared a randomly assigned treatment (i.e., PjBL) group with a control group instructed through a traditional teaching method. The PjBL group had to formulate a group project plan, apply the project, prepare and give a presentation on it, and evaluate the project. No information is given on the activities in the traditional teaching method. The Science and Technology Teaching Achievement Test was used as a pre-posttest consisting of 28 multiple-choice questions that involved all the subjects in the science and technology teaching course. Post-scores were higher for the PjBL group ($M = 16.696, SD = 3.44$) compared to the control group ($M = 15.091, SD = 3.88$, $t(64) = 2.08$, $p < 0.05$), although the difference was small.

In short, the four studies reviewed here report positive effects of PjBL on students’ learning, but the effects/differences seem small to moderate.

Research on the Effects of CBL

An overview of CBL in health professional education is given in a systematic review of Thistlethwaite and colleagues (2012) from studies published between 1965 till 2010. They concluded that CBL can be effective for health professional education, but at the same time, they signal that “there is patchy and inconclusive evidence that it is more effective than other methods” (Thistlethwaite et al., 2012, p. e434). The authors refer to problems regarding sample size, descriptive data, duration of interventions, and longer term evaluation.
In a systematic review of Chen and colleagues (2013), CBL was investigated in the education of traditional Chinese medicine. The definition of CBL employed focused on the presence and solution of problems/cases to stimulate the acquisition of knowledge, skills, and attitudes. Twenty-two articles were included in the review, of which 19 reported effects of CBL on knowledge (i.e., diagnostics, Chinese medicinal herbs, prescription, acupuncture, etc.). Seventeen students showed positive results of CBL over traditional instruction, while two articles found no differences. Four studies reported the effects of CBL on students’ professional skills (i.e., diagnosing, syndrome differentiation, and treatment skills, evaluated by students’ scores on a course test) of which three studies revealed a positive effect in favor of CBL compared to a traditional method.

Brown, Pond, & Creekmore (2011) investigated the impact of a CBL course in toxicology on students’ performance both on a standardized exam (i.e., Pharmacy Curriculum Outcomes Assessment—PCOA) as on their performance on two subsequent pharmacotherapy units. The cases used were, for example, a report of a poisoning or accident, and then several questions were written to encourage students to fully explore each case for which students had to decipher the offending agent in the poisoning, rationalize their finding, and make appropriate recommendations for the patient’s treatment, making use of knowledge and skills from other courses as well. Students who took the toxicology course scored significantly higher on the toxicology subsection of the PCOA, compared to students who did not take the course. However, on the overall PCOA score, no significant differences were found. Further, being enrolled in the toxicology course was related to increased performance on one, but not on the other subsequent pharmacotherapy units. It should be mentioned in this respect that both groups under study differed in exposure to subject matter, which makes that these results should be interpreted with caution.

Farahani and Heidari (2014) assigned 27 Iranian midwifery students to either a CBL or a lecture-based group. The intervention took place over four 90-minute sessions. The CBL group was presented with a clinical case containing patient history, problem details and suggested answers. Students had to think about and discuss the potential diagnosis, treatment, and follow-up and were actively prompted to participate in the discussion by asking challenging questions and providing feedback. The lecture-based group received a lecture on the topic (i.e., labour-time and prenatal foetal evaluation and blood group mismatch). Also in the lecture group, questions were asked, examples were given, and the instructor summarized the content at several points. Participants were pre- and posttested using 10 multiple choice questions reflecting knowledge, comprehension, application, and analysis. No statistically significant differences were found on the pre-test, nor on the posttest. However, the low sample size warrants for caution in interpreting the results of this study.

Ha & Lopez (2014) tested whether CBL was successful in teaching health literacy concepts to pharmacy students. The case, presented to 97 students, described a patient with limited health literacy, and students had to evaluate and formulate a care plan. A pre-posttest design was used and consisted of multiple choice and true/false questions measuring, for example, students’ knowledge on health literacy concepts and abilities to identify risk factors and common signs in patients with limited health literacy. A statistically significant increase from pre- ($M = 6.9, SD = 1.5$) to posttest ($M = 9.4, SD = 0.8$) was observed.

O’Flaherty and McGarr (2014) investigated the potential of CBL to promote moral reasoning in second-year undergraduate students of a teacher education program.
A pre-posttest design quasi-experimental design was used. The control group consisted of the last cohort of second-year students before CBL was implemented in the program under study and having taken the Defining Issues Test (DIT—see below). Program content and structure had not been changed since then and students were similar in demographic characteristics. The CBL intervention consisted of presenting students with classroom scenarios (e.g., how to handle a disruptive class) they were likely to encounter during their placement. The scenarios were discussed in smaller groups and each of these groups received additional information on the scenario (e.g., information on the socio-economic background of the class or information on the background of the teacher). This additional information for each group gave students different perspectives of the scenario, which were subsequently discussed in the whole class. Moral reasoning was measured using the DIT, an instrument consisting of 12 short statements about six hypothetical dilemmas, reflecting Kohlberg’s stages. No differences were found on the development of moral reasoning (weighted average) between both groups pre- and postintervention, as both the experimental and the control group increased their moral reasoning scores from pre- to posttest. However, when another score of moral reasoning was taken into consideration (i.e., the weighted average adjusted for the ability to discriminate between lower and higher stage DIT statements), the experimental group still showed an increase in scores from pre- to posttest, while the control group scores’ remained stable.

Yalçınkaya, Taştan-Kırık, Boz, and Yildiran (2012) compared two groups of eleventh-grade high school students, a CBL and a control group, on their conceptual understanding of chemical kinetics. The intervention lasted seven weeks with three class hours per week. The experimental group used cases in learning the basic concepts of chemical kinetics, while control group was instructed traditionally. Hence, in both groups, students learned the same concepts, but with different teaching methods. A case consisted of a question such as: “Why does cutting an onion into pieces fill our eyes with tears?” supplemented with information from the Internet about this issue and a series of questions for students to look into in small groups and present to the whole class later on. Conceptual understanding of chemical kinetics was measured by the Reaction Rate Concept Test (RRCT), which includes a combination of multiple choice and justification questions. While no differences were present on the pretest between both groups (CBL: $M = 8.08, SD = 2.78$; control: $M = 7.10, SD = 2.75$), statistically significant differences could be observed in the posttest (CBL: $M = 15.68, SD = 2.57$; control: $M = 12.75, SD = 4.12$, $F(1, 51) = 9.347, p < 0.05, \eta^2_p = 0.15$, indicating a strong effect).

Finally, two studies looked at the effects of CBL in nursing education on problem-solving (Yoo & Park, 2014) and communication skills (Yoo & Park, 2015). In the 2014 study, graduate nurses were assigned to either a CBL or a lecture-based group. In the CBL group, graduate nurses were divided into groups of 5–6 participants each and 1 facilitator. Cases were constructed based on frequently occurring clinical nursing problems that may potentially lead to nursing errors and were designed in a video format. The different CBL steps were: 1) watching the video in which the case was introduced; 2) analyzing the case; 3) small group-discussion about the case; and 4) suggesting proper solutions to the case. Alternatively, in the lecture-based group, instruction was given through traditional lectures. To measure students’ objective problem-solving ability, a test was developed including three cases describing common clinical problems that nurses may encounter in the hospital. The posttest was administered 10 weeks after the intervention and demonstrated a significant difference in favor of the CBL group (CBL:}
$M = 63.87, SD = 5.60$; control: $M = 61.05, SD = 7.10, t = 3.04, p < 0.05$). The same set-up was used to test the impact of CBL on communication skills of sophomore nursing students enrolled in a health communication course (Yoo & Park, 2015). Communication skills were evaluated by the Communication Assessment Tool (CAT). While no differences were noticeable on the pre-test between the CBL and lecture-based group, statistically significant differences could be observed on the post-test (CBL: $M = 58.42, SD = 6.75$; control: $M = 46.64, SD = 9.79, t = 8.36, p < 0.001$).

In general, the studies on the effects of CBL on students’ learning show a somewhat mixed picture, with some studies/outcome variables reporting positive effects and others no effects. In this respect, it should be noted that several studies described above had methodological issues, which makes it hard to draw definite conclusions from the data, as was also highlighted in the review study of Thistlethwaite and colleagues (2012).

**CONCLUSIONS AND FUTURE DIRECTIONS**

What can be concluded from this review of studies on inquiry-based instruction? In order to draw appropriate conclusions, several points of attention should be put forward.

First, some methodological issues can be raised with respect to the studies. For example, it should be noted that not all studies in this review included a control group. Sometimes, significant improvements were found on several learning outcomes from pre- to posttest, but it still remains unclear whether and if so, how much students would have gained from the implementation of a different (e.g., lecture-based) instructional method in these studies. Also, effect sizes are regularly missing in the studies. This makes it difficult to evaluate the scope of a difference that was found. In addition, some studies had relatively small sample sizes and time periods in which a specific instructional method was implemented could vary from three weeks till complete curricula. All these issues ask for caution in interpreting the results. Indeed, Eslami, Bassir, and Sadr-Eshkevari (2014) highlight this issue in their systematic review of the effects of PBL in prostodontics (i.e., dental prosthetics). They found that 30% of the studies adopted a control group for all measurements, 30% did for only some measurements, and the others lacked any control group. Many studies did not mention the type of PBL and, when rating the quality of the studies (i.e., based on the Effective Public Health Practice Project), studies were generally classified as being of weak quality. Due to the heterogeneity across studies in outcome variables, study designs, levels of PBL intervention, and study population, generalization of outcomes was difficult.

Second, not all studies provided a clear and detailed description of the instructional approach used. Given that all approaches fall under the umbrella term of inquiry-based instruction, overlap could be observed in several articles. For example, some studies on PjBL cited PBL literature in their theoretical framework. Also, most articles investigating CBL speak of “problems” that are discussed, and preparation of the case according to Barrows’ (1986) definition is usually not mentioned in the articles. Although we attempted to carefully categorize the different studies into IBL, PBL, PjBL, and CBL, the information needed to make these categorizations was restricted to the descriptions given in the articles.

In summary, the review of articles on the effectiveness of inquiry-based instruction in terms of knowledge and skills showed overall positive results for IBL, PBL, and PjBL. However, for IBL and PjBL, some caution is warranted given methodological issues.
and small to moderate effects. For CBL, the review outcome was rather mixed, with some studies demonstrating positive effects, whereas others did not. However, also for CBL, methodological issues played a role. All in all, taking into account the aforementioned points of attention, inquiry-based instruction seems to hold some benefits for students’ learning outcomes. Further, the review’s studies report effects of inquiry in different populations, justifying the claim that inquiry-based instruction might work for learners of a different age and background.

In a way, we have provided a limited review of studies, since we only focused on studies that included knowledge and skills measures measured in an objective (i.e., not self-report) way and discarded other variables that might influence students’ learning. But as mentioned before, these are the variables that are often valued most in the context of effectiveness. However, in the next section, suggestions are made for other lines of research on inquiry-based instruction.

**FUTURE DIRECTIONS: IF, WHY, WHEN, AND FOR WHOM?**

If we want to get a decisive answer about the effectiveness of inquiry-based instruction above direct instruction, future research should focus on randomized controlled studies, such as the study of Wilson and colleagues (2010). As mentioned previously, the number of controlled studies comparing inquiry-based instruction with more direct instruction is rather limited. These studies are, however, crucial to determine whether inquiry-based instruction is effective.

Nevertheless, future studies should not be limited to the _if_-question, but should also take into account _why_ a specific inquiry-based method yields benefit for students’ learning. In other words, more emphasis should be laid on crucial elements and activities. Although this was not the focus of their study, Wilson and colleagues (2010) also tested whether both instructional methods that were compared had the intended outcome in the classroom. Each class session was observed by three external researchers, who took notes and completed the Reformed Teaching Observation Protocol (RTOP) for each unit. In addition, classroom sessions were videotaped and activities in the class were coded to map differences between both enactments. Similarly, a recent study looked closely into why students benefit from group discussion in a PBL context by analyzing video footage of tutorial groups. Results demonstrated that actively providing explanations during a discussion appeared crucial and resulted in benefits for long-term memory performance (Van Blankenstein, Dolmans, Van der Vleuten, & Schmidt, 2011). Studies like these are crucial for unraveling reasons behind students’ differences in different instructional approaches.

Finally, a lot is still to be explored with respect to _when_ inquiry-based instruction is effective. Hmelo-Silver, Duncan, and Chinn (2007, p. 105) state in this respect:

> But we would argue that “Does it work?” is the wrong question. The more important questions to ask are under what circumstances do these guided inquiry approaches work, what are the kinds of outcomes for which they are effective, what kinds of valued practices do they promote, and what kinds of support and scaffolding are needed for different populations and learning goals.

Hybrid forms of student-centered instruction might be considered as well in this respect. For example, Baeten, Dochy, and Struyven (2013) found positive effects in terms of students’ learning approaches when gradually implementing CBL besides
traditional lectures, compared to complete case-based instruction. Qualitative analyses revealed that students appreciated the variation in teaching methods.

Finally, the issue of the different populations in the quote of Hmelo-Silver and colleagues (2007) addresses yet another question: for whom? Effects of instructional approaches cannot make claims about individual students’ learning. It should be taken into account that “a curriculum is a potpourri of individual components, making it difficult to establish links between specific aspects of the curriculum and student behavior” (Norman, Wenghofer, & Klass, 2008, p. 795). Although our review included different populations (i.e., K–16 and higher education), future research should investigate interactions between aptitude and instructional approach in greater detail. Irrespective of whether a learning environment or educational practice is labeled as inquiry-based or direct instruction, educators’ main challenge still remains to foster and promote meaningful learning and understanding within all learners.

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