Changing face-to-face communication

van Diggelen, Wouter

2 Research Approach: Understanding through Design

We might compare the animal's successful solution to an *expectation* and hence to a *hypothesis* or a *theory.*

Karl Popper[1]

The research that is discussed in this thesis follows a *problem-solving paradigm* that considers the design process as a means to advance scientific understanding. The aim of the design is to intervene in an existing learning situation with the aim to improve that situation. In our case, the design intervention affects the communication between students who meet face-to-face to discuss a problem. One of the most noticeable outcomes of the design process is a concrete artifact, in our case a collaborative tool to support face-to-face discussions. Another result of that process – less tangible but of equal importance – is increased understanding, or what Winograd and Flores (1986) referred to as "*the interaction between understanding and creation*".

When designers engage in a design process, they become more knowledgeable about the situation that is addressed by the design. They begin with some initial understanding of the problems that the design aims to solve. These initial conceptions are formulated as expectations that usually stem from designers' knowledge and experience gained during previous design projects. From there they move towards a deeper understanding of the situation: insights in the problems and possible solutions begin to take shape when the designers take into account the subtleties of the design situation. Initial expectations are continuously evaluated and refined so that they better fit the designers' perception of the situation. This process of progressive understanding

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1 The citation comes from a talk given by Karl Popper on the North German Radio (NDR) on March 7, 1972. The talk has been published in Popper, K. (1999), *All life is problem solving*.

applies for the professional designer but it also holds true for the design-based researcher. Exactly this process of "*understanding through design*" comprises the essence of the approach that shapes the research activities that are discussed in this thesis.

In this chapter, we present a research approach that utilizes the design process as a means to generate new knowledge. The chapter starts with a discussion of *Action Research* as one of the first strategies within the Social sciences that considers action, or more precisely real-life problem solving, as a valuable means for research. Next, we present two recent lines of thought from the fields of Information sciences and Educational sciences that give a central place to design as a genuine research activity. We explicitly choose these two disciplines because the research that is discussed in this thesis lies at the intersection of the two: the research intervenes in an existing learning situation and comes up with a technical solution that has its roots in the Information sciences. The first line of thought considers *Design science* (March & Smith, 1995) as a valuable method for Information systems research, while the second line of thought from the Educational sciences sees *Design-based research* as a means to integrate the design process with research (Edelson, 2002). The two lines of thought provide the proper ground for a design-based research approach. Before we address that approach, we introduce the concept of *design patterns*. This concept provides us with a practical orientation towards the design-based research. Design patterns aim to establish a proper fit between the design and the context of use. Furthermore, the method adopts a specific language that makes knowledge about the design process explicit.

2.1 Action Research

Action research is one of the first research strategies within the Social sciences that combines action with research. The origin of the approach can be traced back, among others, to the work of the psychologist Kurt Lewin who is known for his dynamic field theory (Lewin, 1936). The dynamic field theory states that human behavior is the resultant of the totality of facts that act upon an individual or a social system. These facts form a social field of interdependent forces that are in a quasi-stationary balance. These forces have direction, distance, strength, and a point of application (Lewin, 2009). Together they determine the actual behavior of human beings or of the social system they are part of. Lewin applied the dynamic field theory to study the process of social change. For Lewin (1947) any actual social change should come from inside the social system, triggered by people who are part of that system. The scientific method of fact-finding plays an important role in bringing about that social change. It generate valuable insights about the forces that act upon the system.

Action research holds a clear position about the role of the researcher. The researcher, who maps the forces that act upon the system, is not an outside observer. Lewin opposed the idea of a researcher who studies a social system as an independent observer. He states that a social system is difficult to understand from the outside, it can only be known when the researcher interacts with the people that are part of the system and looks beyond the observable to map the underlying facts. Furthermore, Lewin argues that the researcher who wants to understand a social system should exercise influence on the field of forces that determines its behavior (Boon, 1989). It means that knowledge about the social system can only be obtained through active participation of the researcher in the practices directed at improving the system.

Lewin identified two aspects of a social system that make it difficult for an outside observer to understand and predict what will actually happen. These aspects are: 1) a distinction between the "subjective" and "objective" elements of a social system, and 2) a distinction between perception and action. A social system, according to Lewin, is based on *divergent perspectives* and *subjectivity*. A person or a group perceives its own situation and the situation of others in a subjective way, while other groups or persons in that same system may perceive that situation differently. The resultant of these subjective perceptions predicts the *actual or objective actions*. Any change in the social system must take these two aspects – subjectivity versus objectivity and perception versus action – into account. Going from perception to action and from subjective to objective and back again, are no arbitrary demands of a scientific methodology but they mirror a basic property of social life (Lewin, 1947).

It is evident why action research uses real-life problem solving as a research method. Action as the basis for research can be associated with the way that social reality is viewed: dynamic field theory requires that the researcher is involved in activities that aim to change a social system. It makes clear that a methodological framework is closely related to the "way of thinking" (Sol, 1982). In chapter 3, we further elaborate on this issue. In that chapter, we relate an ontology with a methodological framework and a basic theoretical position, i.e. systems thinking, design-based research and the functional perspective.

A Cycle of Related Activities

Action research is based on the active involvement of the researcher in the social system that is the object of change. It combines action with research that is carried out during a process of successive activities. Kurt Lewin (1947) defined action research as "a spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the result of the action". Various researchers from different scientific disciplines have elaborated on this cycle (see e.g. Checkland & Howell, 2007; Reason & Bradbury, 2006; Carr & Kemnis, 1986; Susman & Evered, 1978). Susman and Evered (1978), for example, came up with an action-research cycle that consists of five steps that resembles Dewey's (1933) description of reflective thinking (Figure 2.1). The steps are closely linked; they consist of diagnoses, action planning, action taking, evaluation and the specification of learning. This cyclic character of the research is also an essential aspect of the approach that is followed in this thesis. It emphasizes that research findings are never definite.

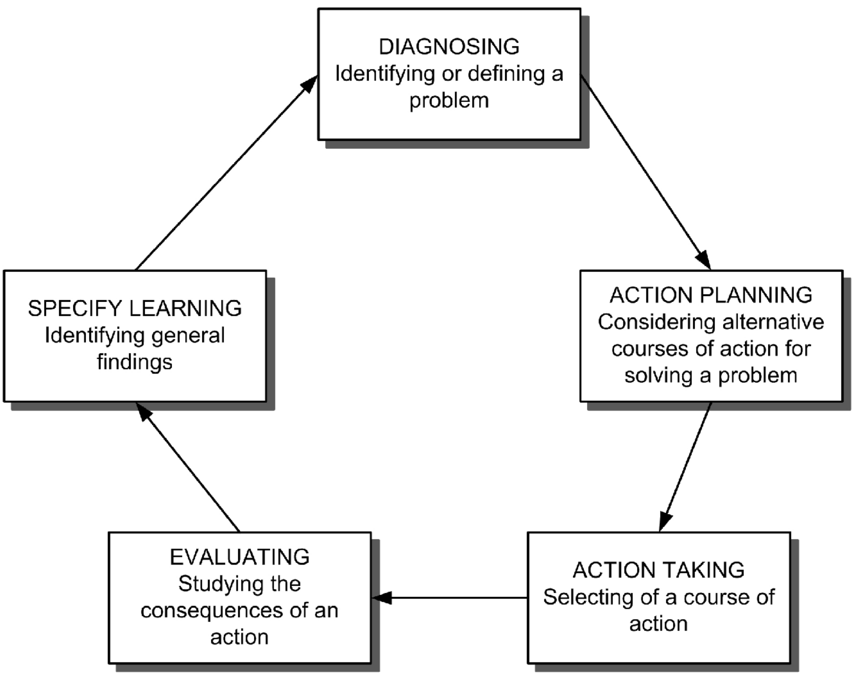

Figure 2.1: The cyclical process of action research (Susman & Evered, 1978).

The Primacy of Action

It is not our intention to discuss action research into detail. What is important is that action research focuses on interventions in naturalistic settings. The research interventions or actions exert their influence on the forces that together determine the behavior of the social system. These interventions aim to improve the performance of the system. At the same time, they provide an opportunity for learning (see Figure 2.1). Knowledge development is closely linked with action. Knowledge generated through research is more practical of nature than theoretical because understanding emerges when practical problems are solved. Action research goes beyond the notion that theory informs practice, to a recognition that theory can and should be generated through practice (Brydon-Millar, Greenwood & Maguire, 2003). Conceptual models emerge from the data, rather than being tested against that data (Kock, 2003).

Action research, in our view, seems to ignore the "re-framing" character of theories. Theories shed a different light on practical problems while hypotheses that stem from these theories lead to new solutions for existing problems. In the next two paragraphs, we turn our attention towards to two more recent research strategies that stresses the interrelatedness of practice and theory.

2.2 Design Science

The aim of Design science is to improve organizational practice by developing novel technological solutions, models or methods. The root of Design science can be traced back to the work of Herbert Simon (1996) who made a distinction between two worlds – a natural world and an artificial one – that are studied by different scientific disciplines. While the natural sciences study natural objects, the artificial sciences study artificial objects created by humans. Simon (1996) stated that the boundaries of the artificial sciences are set by the objects of study:

1. Artificial objects are synthesized by human beings although it is not always that deliberately.
2. Artificial objects may resemble the appearances of natural things while lacking, in one or many respects, the reality of the latter.
3. Artificial objects can be characterized in terms of *functions, goals and adaptation*.
4. Artificial objects are often discussed, particularly when they are being designed, in *prescriptive* as well as descriptive terms.

Artificial objects encompass a broad domain. They do not only include material objects but also comprise cultural artifacts like language that mediates human behavior.

Simon's notion of *the sciences of the artificial* does not limit scientific method to the testing of a theory through research. The design process that is concerned with the creation of an artifact can also be used to generate new insights. March and Smith (1995) spoke in that context of *Design Science* as an approach that produces and applies knowledge of tasks and situations to create effective artifacts. Hevner, March, Park and Ram (2004) stated that research involves the creation and evaluation of information-technology artifacts intended to solve relevant problems. They formulated seven guidelines for Design Science in Information Systems Research (Table 2.1).

The guidelines of Table 2.1 guarantee that the design process becomes an opportunity for research. First, the design process should fulfill the requirements of effective problem solving. It addresses relevant problems and comes up with valuable solutions that are thoroughly evaluated. Secondly, the design process should be relevant for those who are affected by the design. It means that the research activities address

Guideline	Description
Design as an artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Problem relevance	The objective of design science research is to develop technology-based solutions for important and relevant business problems.
Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluations methods.
Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and /or design methodologies.
Research rigor	Design research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Communication of research	Design science research must be presented effectively both to technology-oriented as well as management-oriented audience.

Table 2.1: Design science research guidelines (Hevner, March, Park & Ram, 2004).

business needs (Hevner & March, 2003). Thirdly, the research requires the application of rigorous methods in both the construction and evaluation of the designed artifact (Hevner et al., 2004). The design must be firmly grounded in a sound conceptual framework, while the evaluation of the design should be based on appropriate methods.

Theory plays a rather modest role in Design science, at least compared to those research strategies that empirically test theories. The design of an artifact is based on theoretical insights. However, existing theories are often insufficient. Researchers also rely on experience, creativity, intuition, and general problem-solving methods (Hevner & March, 2003).

The Inductive Hypothetical Research Strategy

The inductive-hypothetical research cycle (Sol, 1982) can be characterized as an early instantiation of Design science. The inductive-hypothetical cycle utilizes the problem-solving process as a means for research. The strategy takes real-life situations as the starting point for research. Characteristic for the inductive-hypothetical cycle are the various steps between the identification of problems and the formulation of solutions. These steps further conceptualize the problem situation. Sol (1982) argued that a problem needs to be conceptualized and specified before it can be solved. It means that each step of the inductive-hypothetical cycle leads to the construction of specific model types that deepen the researcher's understanding of the situation.

The inductive-hypothetical model cycle (Figure 2.2) consists of five steps: initiation, abstraction, theory formulation, implementation, and evaluation (Churchman, 1971; Bosman, 1977; Sol, 1982; de Jong, 1992). The model recognizes

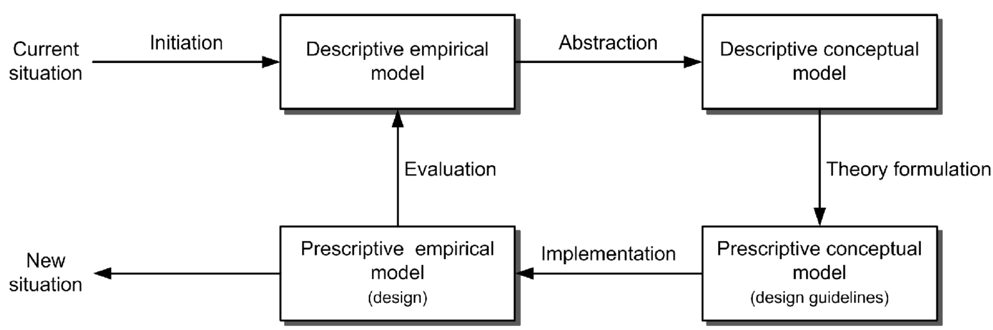

Figure 2.2: The inductive-hypothetical problem solving cycle.

that the researcher enters a design situation with a set of preconceptions or a "way of thinking" that determines the way a problem is conceptualized. The researcher perceives the current situation through a lens (Keen & Sol, 2008) that distinguishes between essential aspects of the problem situation. That lens reflects a basic choice with regard to "how and what to see in the world". It guides the construction of a descriptive empirical model of the current situation that – just like a theory – is an interpretation of reality (Morgan, 1986). For example, in our case we look at collaborative learning from a functional perspective that states that the performance depends on how well communication functions within the context of a group to satisfy requisite conditions for successful learning (Waldeck, Shepard, Teitelbaum, Farra & Seibold, 2002).

The descriptive *empirical* model guides the subsequent activity of abstraction that leads to a descriptive *conceptual* model that describes the mechanisms that explains essential aspects of the problem situation. A description of these mechanisms is important for the subsequent research activities that mark a transition between descriptive towards prescriptive models. It stresses that finding mechanisms does not only satisfies the yearning for understanding, but also satisfies the need for control (Bunge, 2004).

The next activity of theory formulation characterizes a change in orientation from problem definition towards problem solving, that is from descriptive towards prescriptive models. The aim of this activity is to *find appropriate solutions* for the problems that are conceptualized and specified during the previous two steps. The alternative solutions are worked out in '*to be*' models (Janssen, 2001). They consist of a set of design guidelines that represent alternative solutions. The next activity of *implementation* makes the guidelines operational, which results in a prescriptive empirical model such as an artifact or a set of actions that aims to change the current situation.

Linking Practice with Theory: Solution Finding

The inductive-hypothetical cycle can be typified by a number of transitions from descriptive towards prescriptive, from empirical towards conceptual and vice versa. These transitions link practice with theory. Practical problems are conceptualized and specified during the first two steps. The outcome of these two steps – a description of the mechanisms that explain the problem – gives rise to the actual problem-solving activities. The transition from a descriptive towards a prescriptive model can be characterized as theory formulation. Theories set the direction for the solutions that are laid down in the prescriptive models. The concept of "theory" is used in a general sense and indicates an explicit and elaborated set of solutions for the original problem statement (van Meel, 1994).

In the next paragraph, we further elaborate on the "theory formulation" activity of Figure 2.2. We discuss a research strategy – Design-based research – that stems from the Educational sciences. This strategy considers the transition from descriptive towards prescriptive as the formulation of a set of hypotheses that clearly state how the situation will change when the solution is implemented.

2.3 Design-based Research

Design science is associated with the field of Information Sciences but the research strategy has its counterpart in Educational sciences. Design-based research (Brown, 1992; Collins, 1992; Gravemeijer, 1994; Hoadley, 2002) is a research approach within the Educational sciences that integrates the design process as part of general research approach.

Design-based research marks a shift in focus from the study of individual cognition towards the study of cognition in context. It can be contrasted with the experimental approach that is illustrative for cognitive studies (Table 2.2). The cognitive perspective focuses on distinguishable aspects of human cognition. It decomposes the complexity of human cognition into identifiable processes that are carefully studied by manipulating a number of conditions within the environment (Greeno, 1998). More recently, researchers began to study "learning in the wider sense" (Brown, 1992). They began to pay attention to the learning processes as they emerge in real-life settings such as the classroom. This cast doubt on the traditional methods of research: Paradigms that simply examine learning in terms of isolated variables within the laboratory or other impoverished contexts of participation will necessarily lead to an incomplete understanding of their relevance in more realistic settings (Barab & Squire, 2004; Brown, 1992). This change in research focus and method is closely related with the development of situated and constructivist learning theories that take into account the social and cultural context within which learning takes place. Situated and constructivist perspectives make room for alternative research strategies that study learning in naturalistic settings.

Category	Experimentation	Design-based research
Location of research	Conducted in laboratory settings	Occurs in the buzzing, blooming confusion of real-life settings where most learning actually occurs
Complexity of variables	Frequently involves a single or a couple of dependent variables	Involves multiple dependent variables
Focus of research	Focuses on identifying a few variables and holding them constant	Focuses on characterizing the situation in all its complexity, much of which is not know *a priori*
Unfolding of procedures	Uses fixed procedures	Involves *flexible* design revision in which there is a tentative initial set that is revised depending on their success in practice
Amount of social interaction	Isolates learners to control interaction	Frequently involves complex social interactions with participants sharing ideas, distracting each other, and so on
Characterizing the findings	Focuses on testing hypothesis	Focuses on the development of models that characterizes the design in practice
Role of participants	The researcher makes all the decision	Involves different stakeholders who bring in their differing expertise into producing and analyzing the design

Table 2.2: Comparing psychological experiments and design-based research methods (Collins, Joseph & Bielaczyc, 2004; Barab & Squire, 2004).

The Role of Design and Research

Design-based research aims to improve a learning practice; it employs the design process to generate scientific insights. The approach combines *educational research* with *theory-driven design* in order to produce new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings (Barab & Squire, 2004).

Theory-driven Design

The design-based research approach does not merely study empirically what works. The *creation* of new learning activities is critical, not only to evaluate hypotheses but also to develop models and theories. The design-based research approach starts with the analysis of problems in actual learning settings. The problem analysis characterizes the goals, needs, or opportunities that a design intends to address, together with the challenges, constraints, and opportunities presented by the learning context (Edelson, 2002). The problem analysis gives rise to the formulation of an initial set of hypotheses and principles that guide the subsequent design process. Educational designs are implemented with a hypothesized learning process and the means of supporting it in mind (Cobb, Confrey, DiSessa, Lehrer and Schauble, 2003). Importantly, these hypotheses and principles are not detailed enough to determine every design decision (Edelson, 2002). That is because the hypotheses do not only reflect theory, they also take into account the complexity of the learning setting. Such a real-life setting cannot be fully know beforehand. The researcher must be able to make additional decisions when the educational design is introduced in the classroom. Design-based research can be characterized by continuous testing and refinement of hypotheses that makes the design more appropriate for its context of use. Here, a crucial difference emerges between Design science that was discussed in the previous paragraph and Design-based research. The former stresses understanding before design while the latter emphasize understanding through design.

Educational Research

Research within design-based approach generates insights about the effects of the design. It must account for how the design functions in *authentic learning settings*. These accounts are opportunities to advance the researchers' understanding of teaching, learning or the educational systems. Through a parallel and retrospective process of reflection upon the design and its outcomes, the design researchers elaborate upon their initial hypotheses and principles, refining, adding and discarding them and gradually knit together a coherent theory that reflects their understanding of the design experience (Edelson, 2002). This iterative design process reflects progress in understanding of the learning situation.

2.4 The Practice of Design

Design science and design-based research suggest several general directions for research: the research must deal with real-life problems that matter and it should reflect characteristics of effective problem solving. We further elaborate on these requirements by discussing the concept of design patterns.

A design pattern describes a *solution* for a recurrent *problem* that takes into account the *subtleties of* the *context* in which the problem occurs and the solution is implemented. The concept originates from architecture and was first introduced by Christopher Alexander as a description of a problem which occurs over and over again. A design pattern describes the core of the solution to that problem in such a way that you can use that solution a million times over, without ever doing it the same way twice (Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King & Angel, 1977). The notion of design patterns is an elaborated concept that originally addressed the issue of fit between form and context in architectural design. Architecture is a domain that has a long history of design practice that evolved from “unselfconscious” design, embedded in tradition towards a “self-conscious” design that is based on formal models and methods (Alexander, 1964). The notion of design patterns is a response to the latter.

In unselfconscious cultures, there is a natural fit between the design and the context of use. Designers operate in an architectural tradition that is guided by a set of rules and norms attached to the building habits of that culture. Design and use cannot be separated because those who live in the buildings are the same as those who design and built them. The unity of the two roles leads to fluent adjustments of the design when conditions in the context change. Changes in the context that result in failures in the design – e.g. a shortage of certain building material – are directly incorporated into the design. Necessary adaptations of the design occur at the *micro level* but they are anchored at the level of society because they are incorporated in the traditional building habits. Tradition prevents any radical change in the design, and at the same time, reinforces proven adaptations. Consequently, unselfconscious cultures produce clear design patterns that own their existence to the good fit that they provide between form and context.

Architectural design in modern, self-conscious cultures is faced with more complex design problems. These problems require formal methods that consider the design process in a rational manner. Alexander (1964) discussed the drawbacks of these rational methods: they lead to a detachment of the design process from its context of use. Formal methods separate the problem analysis from the design and the design from use. These methods decompose a complex problem into separate parts that are solved independently, at the expense of an integrated view. Furthermore, formal methods rely on expert designers while users hardly have anything to say. This sets the design process even further apart from its context of use.

Alexander (1964) stated that formal design methods result in a loss of fit between form and context. This misfit can be overcome by the notion of design patterns and the use of a pattern language to express the essence of the design. Patterns represent the organized ways in which people use the material arrangements and the problems they encounter in the course of use (Crabtree, Hemmings & Rodden, 2002).

An Ecological Approach

The notion of design patterns has been applied outside architecture in disciplines like software design, interaction design and educational design. There is the danger that the meaning and use of the concept may change when it is applied to other domains, with the risk that the richness of the underlying method may be neglected (Goodyear, 2004). The notion of design patterns encompasses a fundamental view towards the design process. Characteristic for design patterns is the *ecological approach* that deals with the complex relations between elements of the system and its surrounding context. An ecological approach integrates all the relevant aspects of the design process. It reunifies analysis and synthesis, form and context, and the different actors involved in the design, which results in a product that is optimally adapted to the micro-structures of local conditions and constraints (Lea, 1994).

Pattern Language

Alexander (1979) asserted that the complex structure of a design pattern has to be made explicit. Which brings us to another characteristic of design patterns; they are expressed in a formal language. Design patterns must be made explicit, so that they can be shared and reused. The research approach of this thesis incorporates Alexander's (1979) three-part rule that defines a pattern as a relationship between a certain context, a problem, and a solution. This is seen as a useful means for sharing knowledge about the design. Often, a pattern language is used to communicate the knowledge of the expert who is perfectly aware of the subtle relationships between context, problem and solution. Not surprisingly, design patterns are considered a good candidate within ethnography to give form to the design (Crabtree, 2003).

2.5 Way of Working

The research approach that frames the research has been developed within the context of the LEAD project (van Diggelen & Overdijk, 2006). It took into account the limited time available that we had to develop and evaluate novel solutions for existing problems. The project team stared from scratch had to come up with a working prototype within 18 months.

The approach was inspired by the inductive-hypothetical model cycle (Sol, 1982) that has been adapted to an educational context. The inductive-hypothetical model can be characterized by understanding *before* design. It places great emphasis on the development of empirical models that provide a proper description of the problem. We just lacked the time to develop extensive empirical models that are grounded in several cases. The initiation phase of the project took 6 months after which we moved towards the phase of conceptualization. The problems that guided the research came from educational practice, but our understanding of these problems evolved during the project. In that sense, we were inspired by the design-based research approach that stresses understanding through design.

There was the danger that we might address the wrong problems or that the problems were not properly described. Two strategies were chosen to counteract the danger of insufficient validation. First, we relate the practical problems that were identified at the start of the project to earlier research. In that sense, we use the scientific community as a *community of practice* and searched for confirmation within that community. Secondly, the design process consisted of an iterative cycle of design, evaluation, and refinement of the design. This iterative cycle reflects the notion of co-evolution: understanding of the problems and the solutions co-evolves through a design that is repeatedly framed by practice.

Our research approach incorporates the notion of Design-based research that considers the formulation of hypotheses is essential for design-based research. These hypotheses contain clear expectations of how the design creates specific learning behaviors. They mark the transition from descriptive towards prescriptive models. Subsequently, the research that evaluates the design aims to test and refine the hypotheses. In our case, this is done through micro-level descriptions of communication patterns that are associated with group learning.

The research approach that framed the research activities consisted of five steps (Figure 2.3):

1. initiation,
2. abstraction,
3. theory formulation,
4. implementation, and
5. evaluation.

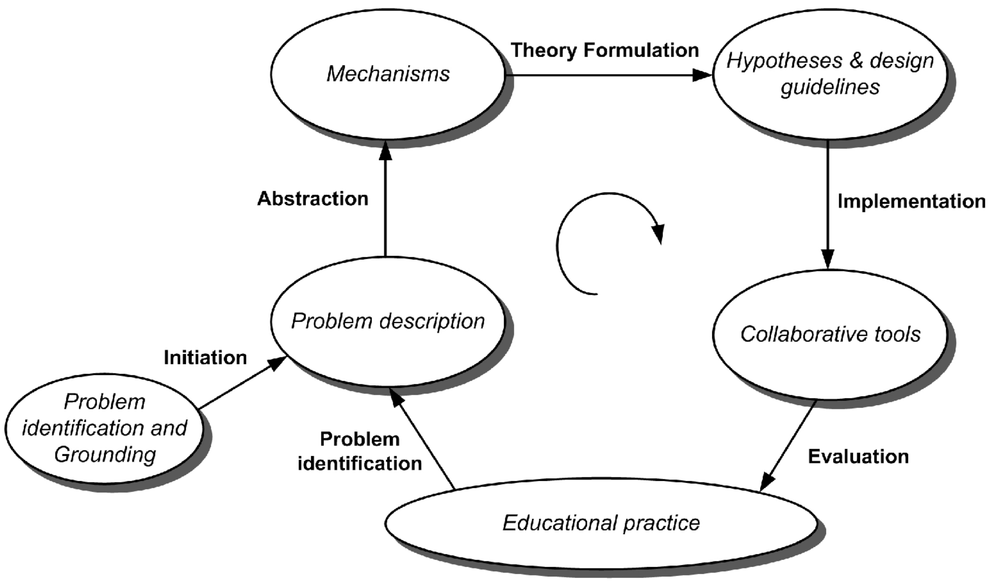

Figure 2.3: Research activities and outcomes.

Initiation: Problem and Context

The research started with a sense that an existing learning situation can be improved. This notion gave rise to an analysis of the human activity system – that is, face-to-face discussions in the classroom – with the aim to describe the *recurrent problems* that affect the learning achievements. The descriptions of the problems were based on empirical observations as well as on insights obtained from studies that are reported in literature. We looked at these problems from a functional perspective that states that group performance depends on how well communication functions. In our case, we focused on the *verbal communication patterns* that can be observed during a face-to-face discussion. First, we defined what constitutes a productive group discussion and identified the *communication patterns* that inhibit groups from learning effectively. During this step we answered the first two research questions (Q1 and Q2) that aim to identify the criteria for a constructive dialogue and the ineffective communication patterns that hamper collaboration and learning.

The initiation phase of the research is described in chapter 4 and 5 where we give a more detailed description of the research context. Chapter 4 provides us with a evaluative framework for analyzing group discussions in the classroom. This framework helped us to interpret the problems that groups may experience during a discussion. In chapter 5 we present some thoughts about learning that we came across in the educational practice. Two dominant views – direct instruction and collaborative learning are explained. Chapter 5 also gives an overview of the various aspects of the learning environment that may affect the research and design activities. The initiation phase ends at the beginning of chapter 6 where we describe a problematic communication pattern – interpersonal dominance – that gave rise to the research.

Abstraction: Underlying Mechanisms

The recurrent nature of the problem implies that it goes beyond a particular situation, in other words, the problem can be described in terms that are more general and still relates to a specific observation. The activity of “abstraction” aims to describe the problems in general terms by describing the *mechanisms* that cause these problems.

The functions-mechanisms relation can be characterized as a one-to-many relation (Bunge, 2004). A function of a social system can be realized through different mechanisms. For example, the sharing of knowledge during a group discussion is usually realized through verbal exchanges. As we will argue in this thesis, groups could also share knowledge with the support of a collaborative tool that mediates their communication. This kind of communication is based on different kinds of mechanisms that performs the same function, i.e. the sharing of knowledge.

The communication patterns that were identified during the previous step are described in terms of the *underlying mechanisms* that organize group talk into a meaningful and coherent whole. This description will answer the third research question (Q3) that provides us with deeper insight in the causes of the dysfunctional communication patterns.

Abstraction does not only deepens the description of the problems identified during the previous step, it also broadens our view of the problems that come into play. A second problematic communication pattern – product blocking – is described at the beginning of chapter 6. This chapter forms the core of this thesis. It describes the three activities of abstraction, theory formulation and implementation.

Theory Formulation: Hypotheses and Guidelines

Theory formulation marks a transition from descriptive towards prescriptive models. The prescriptive models describe the envisioned learning practice. This is done through a process of *interpretation* that draws upon theoretical insights but also on the creativity, intuition, and general problem solving methods of those involved in the design (Hevner & March, 2003). The underlying mechanisms that were identified during the previous step set the direction of change. These mechanisms can be considered as the causes that need to be addressed if any actually change will occur.

The activity of theory formulation results in a number of design guidelines that describe how the envisioned tools affect the current practice for the better. These guidelines are grounded in a theoretical body of knowledge with regard to collaborative learning, group dynamics and computer-mediated communication. They contain a set of hypotheses that set the direction of change that the design will bring about.

General and Specific Guidelines

The collaborative tools that are part of the networked-learning environment must be used effectively in different kinds of learning situations. These situations differ considerably: for example, the group size may vary, the educational level can range from secondary to academic education, and various collaborative learning activities are supported. In sum, the collaborative tools remain more or less the same while their usage differs from situation to situation. This seems at odds with the need of a good fit between the tools and a specific context of use. To solve this issue we made a distinction between two sets of guidelines: general guidelines and specific guidelines.

General guidelines apply to a variety of collaborative learning situations. They have to do with the fundamental change that the tools will bring about. These guidelines describe the basic properties of the collaborative tools. It means that any adaptation of a general guidelines creates a fundamental different kind of support.

Specific guidelines make the general guidelines applicable to a specific context. These guidelines preserve the basic properties of the tools from situation to situation. They ensure that the intended effects associated with the basic properties actually do occur in a specific learning situation.

The specific guidelines are suitable for micro-adaptations; they can be adapted to the specific context of use. Not every guideline can be adapted that easily without affecting the basic properties of the tools. Micro-adaptations aim to solve practical issues that slightly vary from situation to situation. The specific guidelines, in our case, relate to the instructional strategy that accompanied the introduction of the tools.

Implementation: Functional Models

Implementation is a natural continuation of the previous activity of theory formulation. The essence of the tool design is to translate the design guidelines that were formulated during the previous step into a functional model and subsequently to a concrete product. The functional model prescribes the functions and appearances of the envisioned collaborative tools. It refers to an object, often a sketch, model or a set of instructions that is a preliminary stage in the process that leads to the finished product (Raizman, 2003). At a more abstract level, the tool design consists of a set of guidelines that lay down essential aspects of the collaborative tools. At a more tangible or empirical level, these guidelines are represented as mock-ups, sketches of the user-interface and scenarios that describe the envisioned use of the tools.

Evaluation: A Cycle of Research

The next step – evaluation – addresses the fourth research question (Q4) that evaluates the collaborative tools that were developed during the previous step. The research activities that will be carried out during this step must account for when, how and why the tools function in practice. Through research, we draw conclusions about the hypotheses that form the basis of the design guidelines. Comparing the predictions of the design guidelines with observed data enables the researcher not only to test the design, but also to pinpoint problematic aspects of the design (Poole, McPhee & Canary, 2002). If necessary, the hypotheses, design guidelines, and subsequently the collaborative tools will be adapted.

The activity of Evaluation was addressed by a number of studies that are presented in chapter 7, 8, and 9. These three chapters reflect the cyclic character of the research whereby each study triggers a process of reflection upon the design and its outcomes. After each study we evaluated the design guidelines and gradually constructed together a coherent model for computer-mediated communication during face-to-face discussions.

Communities of Practice

Alexander (1964) stressed the importance of an integrated approach that combines all the relevant aspects of the design process, such as thinking and doing, design and usage, solutions and problems, and system and context. Usually, this kind of integration requires considerable application of expert knowledge, rooted in the rich set of experiences of the individual designer or in a history of best practices. Both conditions were lacking in our situation. We did not have "proven solutions" (Haberman, 2006) because we focused on a relatively new situation of mediated face-to-face discussions the classroom. Instead of referring to knowledge and experience of the individual designer, we based the design on scientific knowledge and insights. We used the knowledge that is available in different *communities of practice* (Wenger, 1998), in our case the scientific communities that deal with collaborative learning, the study of groups, and computer-supported collaborative work. The theories and insights that are shared by these communities provide us with the theories and models of how networked learning affects collaboration and learning in the co-located setting of the classroom.

Iterative Design Cycle

Insights in the problem, solution and the context – the three elements of a design pattern – are generated during different steps. The problem description results in the first element: the problem. The set of empirical verifiable hypotheses and design guidelines refer to the second element of the design pattern: the solution. Insights obtained from the research activities lead to the third element: the context of use. Understanding of the three elements co-evolves when the researcher progresses towards a solution that actually works.

The notion of co-evolution implies that the different elements cannot be set apart; their mutual relationships must be taken into account. This requires an iterative design cycle where a solution is evaluated in relation to 1) the problem that it aims to solve, and 2) the context within which problems emerge and solutions are implemented.

Each phase of evaluation, in our case, led to subsequent design cycles where context, problem and solution were redefined because understanding about them has increased. So gradually a more coherent set of design guidelines appeared that reflects progress in our understanding of networked learning in face-to-face situations.