8 Balancing Product Design and Theoretical Insights

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Introduction
Design research has been described ideally as a process of continuous cycles of design, enactment, analysis, and redesign (Design-Based Research Collective, 2003), where the design experiments entail both “engineering” particular forms of learning as well as studying systematically those forms of learning in the context defined by the means of supporting them (Cobb et al., 2003). In practice, though, this research process can be unbalanced and end up with an emphasis on either the design process or theory development. In a professional production environment, there typically will be a strong focus on finishing a product and not necessarily on generating theoretical insights. In academic projects, the focus will be on what new knowledge the project can provide and not necessarily on whether a product is produced and deployed.

The newly established Center for Learning Games at Learning Lab Denmark grew out of a wish to find new approaches to education research in an increasingly complex social context: in Europe, this context is sometimes referred to as a “Mode 2 society.” Using problem-oriented design experiments has proved valuable here. A Mode 2 society is characterized as having heterogeneous criteria and demands on research, emerging from sources outside academia (Gibbons et al., 1994; Nowotny et al., 2001). Thus, it is radically different from a classical “Mode 1 society,” where research questions are solved within well-established disciplines, mainly with internal criteria of quality. Our aim at Learning Lab Denmark is to create methodologies that satisfy these heterogeneous criteria on research by generating new theories about learning, to develop innovative products, and to communicate and support their possible application in practice. We also consider these methodologies relevant for creating organizational changes. These changes always have two objectives: to improve the conditions for learning and to study the changed system. Thus, the purpose of studying the new learning situations goes beyond improving a given product or method. It is equally important to study the social setting that is changing because of the introduction of the new products or learning processes.

Using design experiments as a methodological tool for education research has several advantages. Designing an artifact can act as a source for finding relevant research topics and help to organize the complexity in education research. Also, empirical knowledge about learning is always highly contextualized. Extracting more or less generalizable knowledge from such contextualized phenomena requires conscious choices and value judgments. In an effort to give the reader an overview of the process of doing research projects within these methodological concepts, we have generated an “osmotic model” (see Figure 8.1), which shows the give-and-take between designing artifacts and developing theoretical insights. The left circle mimics the traditional way of doing education
research, where the main “customers” are the peers. The right circle mimics a normal production cycle, but with a much stronger involvement of user feedback. Ideally, a design research project moves in synchronous circular movements, starting from the center and going in both directions. However, this synchronicity rarely happens in practice. Finally, we present three cases as examples of projects conducted at Learning Lab Denmark, demonstrating that real-life research projects can seem like a far cry from the ideals of how to conduct problem-oriented design research.

Case Study One, Mathematical Writing, is an example of a research process that focuses more on the theory-generating part of the process and less on the designing part. The case exemplifies a typical problem in new scientific fields. There are few examples of technological solutions where initial theory generation is crucial in order to be able to do theoretically informed designs of a prototype. Case Study Two is an example of the opposite approach. This case concerns the development of the learning game *Homicide* and how the procedure ended up with a strong focus on the design process and less on the generation of theory, partly because of the demand for developing professional technology for school education.\(^2\) In the last case study, Redesigning Mathematics In-Service Education, we describe a research process that has changed from an ethnographic study of teachers’ practice to a design research process where new means of in-service education are designed. These three cases illustrate how the constraints of various organizational, financial, technical, political, or pedagogical factors make it more or less impossible to implement an ideal or “perfect” research project that maintains a good balance between the processes of product design and theory generation.

**Developing Models**

For the purposes of discussing and maintaining a balance between product and theory generation, a researcher can try to visualize an idealized work flow for a research project. In a problem-oriented approach, the typical starting point is a problem area or the theme that a “problem owner” wants to study and have solved. It also could be called an area of opportunity. Ideally, the problem is investigated by a cross-disciplinary research team, who will collect data in collaboration with the problem owners. The group of researchers might be assembled for the course of the research project only because each new study requires a research team possessing a new combination of competencies (Gibbons et al., 1994). A problem or “opportunity-oriented” approach is not defined normally by a well-established theory within a given paradigm, where a hypothesis can be verified or rejected through empirical investigations and existing
theories can be refined. Rather, an opportunity-oriented approach can use design as a way of finding new approaches and solutions. A design experiment is seen as an iterative process by which better designs can be created. The knowledge production is related to the iterative cycle of design, interventions, and redesign, where value creation is related not only to the application of knowledge but also to the production of knowledge, whereas internal and external communication of knowledge can be qualified by the continuous input of users.

In order to have a model that addresses the push and pull of the work flow in projects, we have developed the “osmotic” model shown in Figure 8.1. This model refers to the process of osmosis because there is an inherent fluctuation between concentrating on designing and reflecting on theory. The osmotic model is not an instruction manual for doing proper research, but merely a simplification for navigating between various aspects of the research process. The arrows are meant to show that there is flow—a dynamic osmotic force. The arrows are not indicators of a sequence or a chronology; rather, they represent phases of a research process that seem to be necessary for the maturity of a design research project. The point of departure is at the center or the “problem”; the optimal research process should be understood as performing iterative and synchronous circle movements in both directions. The word “artifact” should not be understood necessarily as a material object like an abacus or a game; it could be learning strategies, organizational changes, or other intangible process descriptions, which serve as curricular objectives or inspirations for prototypes.

To explain this very idealized and macroscopic model for conducting research, we break down the model into four steps or phases: (a) from problem to design and from problem to hypothesis, (b) from design to intervention and from hypothesis to data, (c) from intervention to artifact and from data to theory, and (d) from artifact to markets and from theory to peers.

From Problem to Design and from Problem to Hypothesis

Going from a problem at hand to a hypothesis or a design entails making a move from the empirical level to the heuristic level, probably the most exciting but also the most difficult part of doing research. A prerequisite is that the researcher has a fairly good knowledge of existing theories about the theme. It also helps to have a sound scientific intuition when making a new hypothesis (a prototheory) about how the particular problem could be confronted and possibly solved. In order to make this move, a researcher should be able to induce a solution; for example, a change of practice. This requires a working knowledge of existing theories, existing artifacts, and design intuition.

From Design to Intervention and from Hypothesis to Data

It is on this level that design research has a great deal to contribute. Design research implies that the move from design to intervention is never linear; rather, it is a circular iterative process. There can be infinite loops of designing, intervening and redesigning. So, like Ptolemy, we ought to draw small epicircles into the figure, between “design” and “intervention” and between “hypothesis” and “data,” in order to acknowledge this fact.

From Intervention to Artifacts and from Data to Theory

Single-classroom interventions and follow-up qualitative research are the prime activities for design researchers at universities. But, in order to maintain the goal of infusing
learning communities with new tools and new ideas, we need to create innovative instructional designs that are readily translatable and adaptable to many contexts. An aspect of this need is preparing the artifact for diverse contexts and not settling for localized prototypes. It is an important goal, and it presents some serious challenges, even obstacles.

From Artifacts to Markets and from Theories to Peers

To ensure successful interventions in education practice, researchers should consider deployment just as important as theory and artifact development. However, there is cause for skepticism. The history of education reform shows us that very little of lasting effect has been produced by education design experiments to date (Williamson, 2003). Some people argue that successful interventions are nothing but a Hawthorne effect (Brown, 1992), that they are too particular and narrow in scope and impact, and that not much can be done to create permanent positive change in classroom teaching and learning. In addition, international studies show it is unlikely that learning will improve markedly by introducing new technologies and media in the classroom without changing the dynamics of teaching and learning (Organization for Economic Cooperation and Development, 2004; Venezky & Davis, 2002) and without including out-of-school activities in order to create inspirational, formal, learning environments (Kozma, 2003).

In addition to the dynamics in Figure 8.1, four conceptual levels are identified. These levels are: the heuristic level, the empirical level, the production level, and the validation level. The heuristic level relates to hypothesis and prototype design, where common sense rules, and intuitions and creative processes are mixed and used in order to increase the probability of finding a good candidate for further inquiry. It involves brainstorming processes, mental experiments of advantages and disadvantages, trial-and-error, and lateral thinking. By contrast, the empirical level tries to systematize what can be known and what is unknown through well-established scientific operands of experiments, observations, verification, falsification, and so on. The production level involves competencies such as organizing, framing, planning, synthesizing, and sometimes delegating work. Last, but not least, the validation level is less in the hands of a researcher than of the people or mechanisms that are used for authentication and dissemination.

Some final comments on the osmotic model. We are proposing that one way to contribute to education reform in the future is to be extremely conscious about creating marketable products that are disseminated to the proper audiences. In this way, we can extend academic validation through peers by external evaluation and selection through users and markets. Thus, evaluation has three facets: peers, markets, and user feedback. “Markets” should not be misunderstood as “mass markets”. Markets should be understood as the many different recipients, target groups, and interested parties of the artifacts in question. These interested parties might be relevant people who have never heard of your artifact, but who might profit from your design efforts. Thus, in order to ensure successful interventions in educational practice, deployment should be seen as being equal in importance to development theory and artifacts.

The Ideal Research Project Versus the Real-Life Challenges

As mentioned before, there may be situations where a design solution is too far removed from the problem at hand. Some fundamental research problems might not yet be suitable for design experiments. Such a situation is described in Case Study One. Also,
the time needed to do iterative research work is often lacking. Design research takes
time because of the need to conduct research on learning in context and to develop
learning materials in an iterative and collaborative process. Sufficient time for develop-
ment is a persistent problem because of the nature of academic funding for blocks of
time or stipends, such as for doctoral dissertations or grants.

Realistically, even though researchers succeed in creating marketable artifacts, there
are other salient issues in schools, such as lack of teacher training, digital infrastructure,
and continuous technical support, that present challenges. The learning context as
a whole—meaning the sociocultural and political ecology and the cultural aspects
(including gender)—is often neglected or downplayed when considering the deploy-
ment and adaptation of new curricular initiatives and artifacts. The later stages of
design artifact and teaching practice involving dissemination and diffusion are gaining
attention in design research. For example, the Integrative Learning Design Framework
(ILDF) devised by Brenda Bannan-Ritland provides an overview of the development
and design process, drawing from traditions of instructional design, product design,
user-centered design, traditional educational research, and web-enabled protodiffusion.
Notably, Bannan-Ritland integrates sociological perspectives on the diffusion of innov-
ations to market (Rogers, 2003; Zaritsky et al., 2003).

Case Studies: Design-Based Research and Mode 2 in Practice

In the following three case studies, we describe some of our experiences with the meth-
odological dilemmas that we try to balance, along with the challenges that we have
faced in practice.

Case Study One: Mathematical Writing

The genesis of this project was to question how technology can support mathematical
writing, similar to the way that prose writing is supported by word processors.
Computers are becoming the widest used medium for written communication. It seems
as if everything, from personal communications and school reports to research articles,
is developed and presented using a computer now. This is a development with many
advantages. As an example, consider how the global internet supports the development
of online learning communities and improves the infrastructure for distributed col-
laboration. Yet, these advantages are dependent mainly on written communication.
Word processors allow for other kinds of writing processes than previous technologies,
which may be due to the printed appearance of text and the minimal effort involved in
restructuring and revising text.

Several attempts to take advantage of the potentials of digital writing in connection
with mathematics, especially mathematics education, seem to be unsuccessful (e.g.,
Guzdial et al., 2002). This observation motivated the mathematical writing project.
Understanding how technology might be able to support mathematical writing can be
considered a very challenging design problem. Our review of the literature (and our
design intuition) indicates that the ideal tool for writing mathematics has not been made
yet, although many candidates have been proposed.

So, instead of starting this project by developing a theoretically informed design of a
prototype, it seemed necessary to understand more fully what people do when they
“write mathematics.” In order to study people in context, we turned to the ethno-
graphic approaches used in the areas of workplace studies and computer-supported
collaborative work. Here, pragmatic versions of ethnography have proved effective for
understanding the problems with existing designs and generating new designs. The ethnographic grounding works well in capturing the complexity of, for instance, collaborative working situations. Figure 8.2 shows the progression of the research, the rationale behind the ethnographic approach, and how it relates to theory and design.

In this approach, the start of the research is a problem or an interesting practice. Then, this practice is observed and described empirically, with attention to the phenomena related to the problem and to keeping a very open hypothesis. These observations should lead to a theoretical description of practice, showing problematic or interesting areas and should provide us with new insights. Design is the expected outcome of the research activity, in the sense that the promise of such research in the long run is a new or an improved artifact that facilitates the practice in question. Figure 8.2 shows this evolution from research, from theory generation to design artifact.

Initial observations about using a computer for mathematical writing were that the existing technology is unsatisfactory and that it is not obvious what to do to improve it. This led us to a methodological approach that is mainly ethnographic. The research focused on what different types of people do when they work with mathematics; that is, how they write, what media they use, what kinds of representations are central, and how they collaborate. Two investigations were done: one with professional mathematics researchers about their various writing processes (Misfeldt, 2004b, 2005b) and one with undergraduate students about their collaborative writing (Misfeldt, 2005a).

The first investigation was based on interviews with mathematics researchers, and consisted of 11 semistructured interviews. During the interviews, the mathematics researchers explained the purposes that writing has for them, both in their individual work process and in their collaborative work processes. The investigation indicated that writing is very important to these researchers in almost all phases of their work. They use writing to clarify early ideas about a problem, using pen and paper in a way that supports thinking. Then, as an idea has to be developed further, writing and doing calculations are crucial. Furthermore, writing is central in collaboration and for saving ideas. Mathematics researchers tend to use pen and paper for calculations in order to support thinking. For many of these researchers, computers become part of the writing process at a very late stage.

The second investigation was a field study of undergraduate students’ collaborative work in connection with completing an assignment. This investigation was based on several data sources. We followed two groups of students, having weekly contact with them and doing video observations of seven of their group meetings. Furthermore, each of the students kept a detailed diary log during one week of work with their assignment.

Figure 8.2 The Ethnographic Approach Taken in the Mathematical Writing Project.
The investigation showed that there is a complex interplay between the use of writing as a personal tool, an ostensive tool, and a product in collaborative writing activities on mathematics.

The results of the two investigations are discussed using a semiotic framework (Misfeldt, 2004a). This framework allowed us to examine the structure of interaction between people and between people and media on the same level. Our field work led to theory-building about how different types of semiotic mathematical representations relate differently to existing writing technology. It seems that for the linear types of mathematical notation, such as algebraic formulas, there is a potential for using the oral register (the way formulas are spoken aloud) as a design heuristic. This heuristic is well known from the way that the Windows-based computer systems handle Japanese character (iconographic) writing. It seems sensible to copy that interaction for developing new formula editors.

We hope that our results contribute to developing principles for the design of a new writing technology. Using the way that formulas are spoken aloud as a design heuristic is not the usual way of designing mathematical writing tools, and it counters most of the existing and new designs. The more diagrammatic or two-dimensional the notation gets, the less meaningful the connection becomes. Hence, other interaction forms are needed. It appears that face-to-face interaction about mathematics draws on several media and that the role of these media changes rapidly between being social and individual. These results are not well suited as a starting point for the design of digital technology, but they could point to developing design principles for working environments and for the organization of collaborative projects.

Case Study Two: Designing the Learning Game Homicide

This project was initiated in 2003 at Learning Lab Denmark and was not set up initially as a design-based research project, but with a Mode 2 approach. The project was an experiment in bringing innovative learning materials to markets; that is, the focus was on deploying new learning materials to schools for further research and development. The artifact is an information technology-supported, role-playing game called Homicide, in which students play forensic experts solving a murder case (Magnussen & Jessen, 2004). In a week-long investigation, students analyze clues, such as fingerprints and blood found at crime scenes, using both theoretical and hands-on, practical methods. The investigations are conducted both in the virtual game space and in the physical space in the schools’ laboratories. The game is a mixed-media supported game, with the main part of the interaction and problem-solving taking place in the social space in the classroom and not as computer–student interactions. The computer serves as a knowledge base that students can consult for such information as criminal investigation handbooks with procedures and scientific background materials, data from crime scenes, video interrogations of suspects, document support, forensic reports, etc. Thus, this game-based learning environment was designed to develop science competencies through simulation of a real-life learning situation.

The goal was to explore the possibilities for developing a learning game that would support working with the scientific method, using a scientific process of inquiry, and still be an exciting game to play. The aspiration was to make a playful, humorous, yet fairly low-budget learning game. We intended the game to be used in schools for integrating different subjects. Aspects of crime stories and real-life, crime laboratory genres from television series were combined with computer games and traditions of “learning by doing” through role-playing and simulation methods.
The development team consisted of a core of people functioning as designers, writers, developers, and researchers. A common feature was that all of the participants had some type of academic theoretical approach to game development as well as a practical, media production background. The team included others as needed: actors, consulting teachers, and specialized education researchers.

The development project had four phases. The first phase was the theoretical founding and conceptualization. The team started with a knowledge-gathering phase, studying the content of the game (forensic techniques) and researching situated learning theory, activity theory, literary theories, and role-playing theories in order to conceptualize the learning structure of the game. In the second phase, the team developed and produced a pen-and-paper version of *Homicide*, which was alpha-tested and generated results on the players’ use of roles and their level of science learning content. The researcher was an integrated part of this process, working primarily with the science learning content. Phase Three was the final stage of the game development period and led to the production of a beta version of the game, which went through several iterations (related to two interventions in schools) before the game design was finalized. The game designers, researchers, and teachers worked together on integrating science learning elements and game elements in the final product. Phase Four included dissemination, teachers’ education, and proposals for future studies of the game as a learning environment. The approach taken in designing *Homicide* is shown in Figure 8.3.

In the two studies of *Homicide* in action, we saw that the game’s learning environment supported working with the process of inquiry and that it was motivating and engaging for students. In the first interventions with the game in school, the social learning in the game-based learning environment has proved highly interesting also. In the observations of the play intervention, we saw not only how the students handled large amounts of data to establish theories, but also how they redesigned the game tools independently in an effort to establish a coherent hypothesis. These tools became increasingly more sophisticated during the week-long play intervention, which seems to indicate that the students not only used individual skills, but also that they operated on a methodological metalevel where tools and methods are evaluated and adjusted to meet the challenges of the game. A theoretical description of this type of simulated, situated, game-based learning space is relevant because we have little knowledge yet about what types of learning processes take place in these kinds of learning spaces, what makes a design effective, and how to adapt findings to other settings. Future, long-term observations and design-based research studies of players playing *Homicide* are needed to gain an understanding of both the theoretical and the learning aspects.

![Figure 8.3 The Product Design Approach Taken in the Homicide Project.](image-url)
The project’s focus was on the development of the game. The initial design concept was theory-driven, but the process as a whole lacked deeper analysis in relation to redesign and theory-building. This problem may be rooted in the balancing of the roles of the developers and the researchers, and this issue may be endemic to design research projects, especially large development projects like Homicide. A team needs to find a common language and cultivate respect for the contributions of each member of the team, yet accept certain limitations on the level of engagement in all aspects. The question here is whether the developers and the researchers in larger development projects should have equal focal points in the research and development outcome of the project or whether they should have separate processes? For example, it may not be possible for researchers to understand and integrate fully the theory that is the focus point of the material produced without being an integrated part of the development process. The designer will not be able to make theory-driven designs without being an integrated part of the research, but there might be processes that are meaningless to other parts. When the game is working well, it might be meaningless to the developer to keep changing elements to get a deeper understanding of the learning processes that the game facilitates. On the other hand, the researcher might find it meaningless to keep adjusting technical details that are unimportant to the research focus. Therefore, one solution could be that the researchers and the designers should consider having certain separate processes.

In regard to changing existing practice, since 2004, the development and research team has been in demand at conferences and the like and has been showcased for the originality of its approach to designing curricular materials and for introducing a new breed of learning materials. Thus, the Homicide game itself does indeed seem to inform educational policies and practice in schools, creating demands for teachers’ training and provoking debates about such issues as curriculum design, cross-disciplinarity, and students’ decreasing interest in learning science.

Case Study Three: Redesigning Mathematics In-Service Education

The goal of this research project was to investigate a narrowly focused curriculum initiative, mediated by an in-service course for mathematics teachers in a traditional Mode 1 type of study. In-service education is the most commonly used way to implement new curriculum initiatives, yet little is known in Denmark about how it influences classroom practice. The initial research questions were: How clearly were the intentions in the initiative delivered in the in-service course and in the classrooms? What was the effect of the teachers’ in-service course on the subject, which was open problem-solving in mathematics?

The background for this project was a new type of oral mathematics examination after grade nine in the lower secondary schools, which became compulsory in Denmark in 1997. According to the governmental curriculum requirements, the examination tasks had to be formulated as practical problems of an open character. This new type of examination led to an in-service course, “Preparing for Mathematics Exams,” offered to mathematics teachers in 1996. These in-service courses were run by pedagogical consultants, but the courses were offered only when enough participants enrolled.

However, there was no concomitant plan for researching how open problem-solving might have positive or negative effects in the classroom. In 2002, a doctoral dissertation research project at Learning Lab Denmark made it possible to start studying the effects of an in-service course on open mathematics problem-solving; namely, how did the in-service course influence teachers to change their practice?
The doctoral researcher started by reviewing curriculum theories and then collected data about the content of the in-service course and the teachers’ subsequent teaching practice. The research question was: To what extent can teaching mathematics with open practical problems be learned in an in-service course by the participating mathematics teachers?

The methodological approach was qualitative, with investigations of teachers’ practice through ethnographically inspired fieldwork and in-depth interviews. The research methods included semistructured interviews (Kvale, 2001; Patton, 2002), video-tapes (Pirie et al., 2001; Powell et al., 2003), diaries produced by the teachers, and materials produced by teachers and students. One of the early research findings was that the in-service course did influence the teachers in using open mathematics problems in the classroom, but, at the same time, using open problems creates a situation of paradigmatic and authoritative flux where continuous immediate decisions have to be made by the teacher. Many of the teacher’s decisions are “uncertain” in the sense that they are made on the spot and in response to local conditions. One of the significant elements of working with open problem-solving is that students ask questions or suggest solutions, for which the teacher cannot always be prepared. Therefore, the teacher has to listen carefully to the student and find quick and suitable responses. The teacher has to concentrate on: What does the student mean? What is the context? What is a good response for this particular student, etc.? However, what typically happens is that the teacher does not listen carefully enough and gives automatic responses, as other research confirms (Jarvis, 1999; Skott, 2000).

Listening and responding become crucial skills when using open problem-solving in the classrooms. The teacher has to listen in another way because open problem-solving can go in so many directions. It seems that teachers stay with their old discourse habits of knowing the answers to all of the questions. Indeed, the new context requires new types of leadership and development of the skill to listen in another way, along with the ability to ask powerful questions and give clear responses.

As the researcher reflected on the early findings, another question appeared: Why does the teacher listen and respond so poorly when students solve open, practical, mathematics problems? With this more narrow focus, the project moved into a design research approach, where part of the focus was on redesigning the in-service course with design experiments, developing instructional activities, and conducting analyses of the processes of the students’ and teachers’ learning and the means by which that learning is supported and organized (Cobb, 2001; diSessa & Cobb, 2004). This approach is shown in Figure 8.4. The project started out with a specific “artifact”—the existing in-service course. This course is being redesigned on the basis of the ethnographic data and theoretical refinements obtained.

The shift into the design research framework gave the study a boost because it made clear to the researcher how to ground the redesign of the curriculum. Based on the interpretation of the research data, the evaluations made by the teachers, combined with material on the stated goals and visions for the mathematics, the redesign of the course explored how to engage the teachers in “reflective cooperation.” The theoretical framework under development was about the similarities and the differences in the school classroom and in the in-service course classroom.

The results of the study show that the teachers took with them back to their classrooms what they had learned at the in-service course. However, the researcher observed that none of the classroom communication came near a kind of “reflective discourse” organized through communication about the open problem-solving. What was the reason for that? How could the in-service course be prepared differently to meet those
needs (needs that the teachers maybe were not aware of)? The new method entailed asking the teachers to keep diaries of the communications in their classrooms and doing self-observation and reflection about their teaching practice in more focused ways. The redesign contained reflective cooperation, which was done by arranging a situation where the teachers could experience their own listening and response activities.

One of the theoretical frameworks used was Leron and Hazzan’s *The Virtual Monologue* (1997), a game whose purpose is to imagine a virtual inner monologue in the communicating persons (Ejersbo, 2005; Ejersbo & Leron, 2005). The crucial point of The Virtual Monologue is to get the teachers to be aware of their habits and to recognize the importance of changing together as a group and on the individual level when they are back alone in their classrooms. It is hoped that this insight will enable the teacher to become aware of his or her ways of listening and responding and, consequently, develop the necessary skills and competencies.

The research project started as a Mode 1 project, influenced by Mode 2 requirements, but it changed in the middle into a design research project. That was possible because the in-service courses continued in a cycle, with a course each year. One of the difficulties was balancing the different roles between being a consultant and being a researcher. The course was redesigned, grounded on the theoretical frameworks from the research. On the one hand, the participating teachers were satisfied still; on the other hand, the redesigned courses were evaluated immediately after the course by the participating teachers only, without any classroom studies. The old courses were very popular too, and a remaining question is how much the new course influences the subsequent mathematics teaching and why. An iterative process can go on.

**Discussion**

The evidence from the three case studies shows that there is no straightforward way to plan and carry out a design research project. There are many possibilities and many caveats and there are no stable methodological paradigms or theoretical recipes by which to proceed. Therefore, as a researcher, one has to be pragmatic about the choices at hand and concede that it may be impossible to do everything at once. Sometimes, it will be unimaginable to do intervention trials; at other times, it will be impossible to deploy an artifact. Sometimes, it may be best to use some heuristics; at other times, applying field studies is sensible if the situation cannot be supported by the designs available.
The approach chosen in Case Study One on mathematical writing was to do fieldwork in order to see what did or did not work in a given context. It was necessary to observe how people use digital and other technologies before creating a “humble” hypothesis and concrete design ideas. Creating humble theories is different from attempting to make a grand or high theory, but certainly appropriate and valuable: “Design experiments are conducted to develop theories, not merely to empirically tune ‘what works.’ These theories are relatively humble in that they target domain-specific learning processes” (Cobb et al., 2003: 9).

In Case Study Three, mathematics in-service education, these two considerations merge nicely. Being a very popular, in-service course, some impact is guaranteed. Nevertheless, the research project has managed to question iteratively the nature of this impact and to feed back the knowledge to a revised version of the course, maintaining a large impact. The question is still to explain in a researchable way why the new designs work and to suggest to which new circumstances they could be adapted. The crucial point in Case Study Three is to keep the balance between developing the course in response to the market condition or the research condition.

In Case Study Two, Homicide, the focus was on the development part of the process, where intuitions and practical experiences were more dominant in the designing of a new type of learning material than theoretical knowledge. It is difficult to say anything definite about what the right balance is between theoretical findings, heuristics, and empirical analysis because it is highly dependent on the context, but it should be something that developers and researchers pay attention to throughout the whole process. Also, in this case study we struggled with the richness of the data embedded in the final design of the game. In the beginning, we were tempted to create a broad, all-encompassing theory on why and how a learning game works. “Beyond just creating designs that are effective and that can sometimes be affected by ‘tinkering to perfection,’ a design theory explains why designs work and suggests how they may be adapted to new circumstances” (Cobb et al., 2003: 9). However, the need to restrict the research questions became clear quickly. The grand questions were broken down into an analysis of details, single parameters, certain context aspects, or a specific hypothesis. Case Study Two illustrates an osmotic pressure, where the concentration of energy was so much on the development of a new type of learning material at the beginning; now, the pull is toward developing the theoretical insights.

There are also lessons to be learned by the design research community. It is not enough to have some nice prototypes that work in some small selected contexts (Barab & Squire, 2004). The production of deployable artifacts is crucial for creating a lasting impact on learning communities, although deployment can be seen as a problem for maintaining an iterative design process. The question of why cognitively oriented, technological innovations have not become widespread has been addressed by Fishman and colleagues (2004), who state that a key reason for the limited impact is that most design-based research does not address explicitly systemic issues of usability, scalability, and sustainability. We agree. Perhaps, popular notions of “demo or die” should be complemented with “demo and deploy” or “meet the market.” We would add criteria of communication and deployment of scientific ideas and artifacts. These criteria can have positive consequences for design-related research.

First and foremost, there is the consequence that the design involved in the research process should be disseminated at some point to some kind of open market, even though this could mean stopping the iterative design process temporarily. The second consequence is to communicate to relevant interested parties throughout the entire research process.
communication should be more than research reports that appear only in specialized journals years after the project is finished.

Conclusions

In this chapter, we have described some of the central methodological considerations in our attempt to make a practice-oriented approach to education research. We have developed an “osmotic” model in order to describe how it is possible to balance the dynamics of a research process. Using this model, we presented three of our research projects and evaluated how they match our ideal of doing education research. The picture that emerges from these three case studies shows that it is hard to achieve our ideal, mainly because it is impossible to address all the aspects involved in the model with full intensity simultaneously. Our advice is that researchers need to select a suitable methodological approach, guided by a combination of analysis and heuristics about the problem, as well as pragmatic concerns about resources, partners, and so on.

We hope to contribute to the development of methodologies in design research. On our side, there are some continuing problems in the choice of approaches, and much work lies ahead in trying to align the work done with the ideals. We understand research contexts as potential, collaborative, idea and theory generators that reach beyond intervention or improving theoretical accounts of teaching and learning. We believe that research results and prototypes should be aimed at different communications areas and that innovative thinking is an issue to consider methodologically. Finally, we think that a wider pragmatic diffusion of pedagogical and didactic innovation in scalable, replicable, and sustainable form is imperative in order to avoid narrow research projects that never reach maturity.

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Notes

1 Science, Technology and Learning Group at Learning Lab Denmark, Danish University of Education website: http://www.lld.dk/.
2 Learning Lab Denmark Homicide project website: http://www.drabssag.dk/.

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