An Introduction to Educational Design Research

SLO • Netherlands institute for curriculum development

Editors:
Tjeerd Plomp & Nienke Nieveen

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Proceedings of the seminar conducted at
the East China Normal University, Shanghai (PR China),
November 23-26, 2007

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Tjeerd Plomp & Nienke Nieveen (editors)

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Preface

This book is the result of a seminar on 'educational design research' organized from November 23-26, 2007, by Prof Zhu Zhiting (Department of Educational Technology) of the College of Educational Sciences at the East China Normal University in Shanghai (PR China).
The primary goal of the seminar was t*o introduce a group postgraduate students and lecturing staff in China to educational design research as a research approach*. The second goal of the seminar was to prepare, based on the contributions of a number international experts, *proceedings of the seminar* written in such a way that they can be used in postgraduate seminars on educational design research across China.

About 75 people with backgrounds mainly in instructional technology, curriculum and instructional design participated in the seminar. Most of them were working in teacher education, in schools as instructional technologist and/or in distance education. Although participants had (through their studies) already knowledge and some experience in instructional or course design and in research methods, they were eager to be introduced to design research as a relatively new research approach for addressing complex problems in educational practice.

The seminar staff consisted of Profs *Brenda Bannan* and *Eamonn Kelly* (both George Mason University, Fairfax, VA, USA) and Prof *Jan van den Akker* (University of Twente and National Institute for Curriculum Development [SLO], Enschede, The Netherlands), and the two editors of this book Dr *Nienke Nieveen* (National Institute for Curriculum Development [SLO], Enschede) and Prof *Tjeerd Plomp* (University of Twente, Enschede, The Netherlands). As can be seen from the table of content of this book, they are reflecting the background of the participants, as they represented experience in conducting design research in the domains of curriculum development, instructional technology and mathematics and science education. Experts were consciously invited from both Europe (The Netherlands) as well as the USA, so as to ascertain that variation in background and perspective on design research was represented in conducting the seminar.

The chapters in this book are based on the presentations and the small group discussions during this seminar. Although the book does not provide a 'how to do guide' for designing and conducting design research, the chapters have been written in such a way that they reflect both the conceptual underpinning and practical aspects of the 'what' and 'how' of doing design research (chapters by Plomp, Kelly and Nieveen), as well as provide the reader an insight in the specifics of doing design research in the domain of curriculum (chapter by Van den Akker) and instructional technology (chapter by Bannan).
To assist the readers in finding their way in the abundance of literature on design research, we have added a chapter with references and sources on educational design research. This

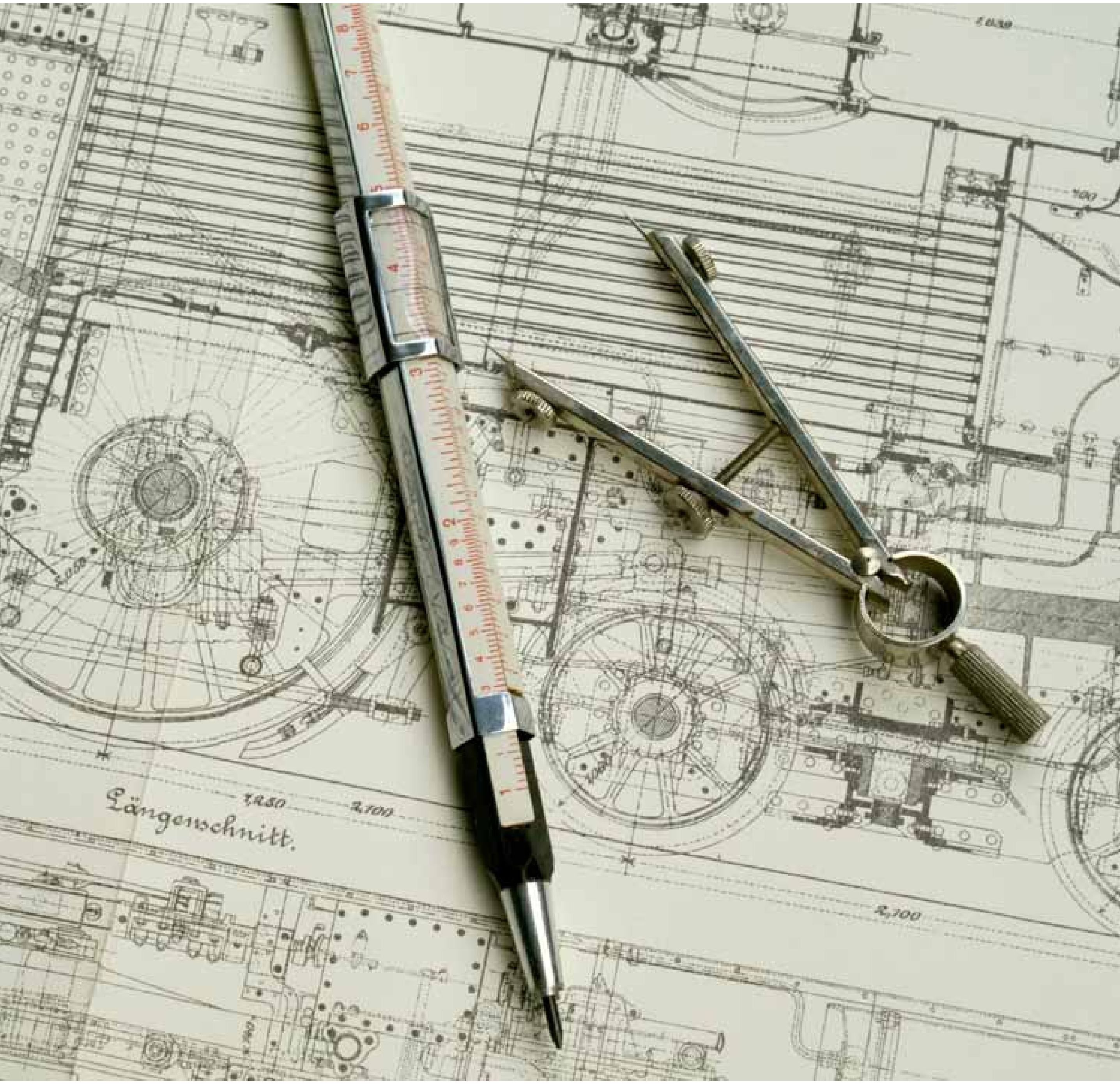
bibliography is far from complete and reflects very much the background and the biases of the editors of this book. Yet we trust that this chapter will assist the interested reader in getting introduced to this exciting and promising research approach.

We want to thank Prof Zhu Zhiting from the East China Normal University for taking the initiative for this seminar. Similarly we want to thank our colleagues for contributing to this book.

But above all, we like to express our hope that this book will stimulate and support many (future) researchers to engage themselves in educational design research.

Jan van den Akker
Director General SLO

Tjeerd Plomp and Nienke Nieveen
Editors


Längenschnitt.

1. Educational Design Research: an Introduction

Tjeerd Plomp

Introduction

The purpose of this chapter is to provide an introduction to educational design research as a research approach suitable to address complex problems in educational practice for which no clear guidelines for solutions are available. Educational design research is perceived as the systematic study of designing, developing and evaluating educational interventions, - such as programs, teaching-learning strategies and materials, products and systems - as solutions to such problems, which also aims at advancing our knowledge about the characteristics of these interventions and the processes to design and develop them.

The need for a research approach that addresses complex problems in educational practice has been argued by researchers in various 'corners' of the domain of education from the lack of relevance of much educational research for educational practice. For example, the Design-Based Research Collective (2003:5) argues that educational research is often divorced from the problems and issues of everyday practice – a split that resulted in a credibility gap and creates a need for new research approaches that speak directly to problems of practice and that lead to the development of 'usable knowledge'.
From his background in research in the domain of *curriculum development and implementation,* Van den Akker (1999: 2) argues that many 'traditional' research approaches such as experiments, surveys, correlational analyses, with their emphasis on description hardly provide prescriptions that are useful for design and development problems in education. He claims that an important reason for design research[1] stems from the complex nature of the educational reforms worldwide. Ambitious reforms cannot be developed at the drawing tables in government offices, but call for systematic research supporting the development and implementation processes in a variety of contexts.
In his review of the state of educational research and more specifically educational technology research, Reeves (2006: 57) concludes that there is "a legacy of ill-conceived and poorly conducted research that results in no significant differences or, at best, in modest effect sizes". He also argues for the domain of *educational technology* that educational technologists, in stead of doing more (media) comparison studies, should undertake types of design research. In other words, Reeves argues that in stead of doing more studies comparing whether in a certain context method A is better than method B, it is better to

[1] which he calls 'development research' in his 1999 publication

undertake design research aimed at developing an optimal solution for a problem in context.
In the field of *learning sciences*, the belief that context matters lead to the conclusion that research paradigms that simply examines learning processes as isolated variables within laboratory settings will necessarily lead to an incomplete understanding of their relevance in more naturalistic settings (Barab & Squire, 2004; with reference to Brown, 1992). In this field, design-based research was introduced with the expectation that researchers would systematically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts (Barab & Squire, 2004: 3).

These sources illustrate the need for design research as an alternative research approach. Before elaborating on design research this paper will first discuss more generally possible functions of research and how research functions are related to research approaches. Then design research will be defined and characterized from various perspectives, such as the type of knowledge the design researchers aim for, the type of research questions that can be addressed, and the outputs of design research. This will be followed by a section in which different approaches to design research are introduced and sections discussing how design research can or should be conducted, with a more in-depth discussion of formative evaluation as the most prominent research activity in design research. Conducting design research puts researchers in a situation in which they have to face a number of dilemmas. These will be discussed before ending the chapter with a few concluding remarks.

A final note on terminology, following Van den Akker et al. (2006:4) we use *design research* as a common label for a 'family' of related research approaches who may vary somewhat in goals and characteristics – examples are design studies, design experiments, design-based research, developmental research, formative research, engineering research.

Research functions – research approaches

Before elaborating on the meaning of design research, it is important to position design research as a research approach next to other research approaches, which is the purpose of this section.

The key focus in all scientific research is the search for '*understanding*' or for '*knowing*' with the aim of contributing to the body of knowledge or a theory in the domain of research. Other *broad aims* of doing educational research are to provide insights and contributions for improving practice, and to inform decision making and policy development in the domain of education.

Research functions

In general, we can distinguish various *research functions*, each reflecting certain types of research questions. Examples of research functions (with exemplary research questions fitting the function) are:

1. *to describe:* e.g. what is the achievement of Chinese grade 8 pupils in mathematics; what barriers do students experience in the learning of mathematical modelling
2. *to compare:* e.g. what are the differences and similarities between the Chinese and the Netherlands curriculum for primary education; what is the achievement in mathematics of Chinese grade 8 pupils as compared to that in certain other countries
3. *to evaluate:* e.g. how well does a program function in terms of competences of graduates; what are the strengths and weaknesses of a certain approach; etc
4. *to explain or to predict:* e.g. what are the causes of poor performance in mathematics (i.e. in search of a 'theory' predicting a phenomenon when certain conditions or characteristics are met)
5. *to design and develop:* e.g. what are the characteristics of an effective teaching and learning strategy aimed at acquiring certain learning outcomes; how can we improve the motivation of learners.

In many research projects the research questions are such that in fact various research functions do apply. For example, if the research question pertains to comparing the mathematics achievement of Chinese grade 8 pupils as compared to that in certain other countries, then as part of *comparing* the researchers will *evaluate* the achievement of grade 8 pupils in each of the countries involved. Or, as another example, if one wants to *design and develop* a teaching-learning strategy for acquiring the competency of mathematical modelling (in grade 11 & 12), then researchers may first want to understand and carefully *describe* what barriers students experience with mathematical modelling, whilst also the *evaluation* function is important in determining whether the teaching-learning strategy that has been developed is effective. Both examples illustrate that usually a research project has a primary research function, but that other research functions are being applied to 'serve' the primary research function.

At the level of a *research project*, starting from a research problem or question, we are supposed to have the following sequence:
R*esearch question => (primary) research function =>choice of research approach*.
In this chapter we focus on research which has *design and develop* as the primary research function.

Research approaches

Most text books on research methodology present and discuss a number of *research approaches* or *strategies* (see e.g. Denscombe, 2007). Usually each research approach can be

used for realizing more than one research function. Without going into detail here, examples of research approaches and their possible research functions are:
- *survey:* to describe, to compare, to evaluate
- *case studies:* to describe, to compare, to explain
- *experiments:* to explain, to compare
- *action research:* to design/develop a solution to a practical problem
- *ethnography:* to describe, to explain
- *correlational research:* to describe, to compare
- *evaluation research:* to determine the effectiveness of a program

Textbooks on research methodology usually do not present and discuss design research:
- *design research:* to design/develop an intervention (such as programs, teaching-learning strategies and materials, products and systems) with the aim to solve a complex educational problem and to advance our knowledge about the characteristics of these interventions and the processes to design and develop them.

In line with the remark that more than one research function may have to be applied to address a research question, it should be noticed that in a research project more than one research approach may have to be applied. For example, if there is a need to compare how well Chinese grade 8 pupils perform in mathematics as compared to a number of other countries, the primary research function is to compare, leading in this case to a survey as the best research approach. However, as part of the development of a valid and reliable mathematics test, the researchers may do correlational research to determine whether the test being developed is valid, i.e. correlates with other measures of mathematics achievement.

As a final remark, it is important that design researchers, like all researchers, keep in mind that also for their research the guiding principles for scientific research (Shavelson & Towne, 2002) apply, viz:
- Pose significant questions that can be investigated
- Link research to relevant theory
- Use methods that permit direct investigation of the question
- Provide a coherent and explicit chain of reasoning
- Replicate and generalize across studies
- Disclose research to encourage professional scrutiny and critique

What is design research?

As stated educational design research is *the systematic study of designing, developing and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them*.
The twofold yield of design research, viz. research based interventions as well as knowledge about them, can also found in definitions of design research by other authors. For example, the broad definition of Barab and Squire (2004) also encompasses most variations of educational design research: "a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic setting.

By its nature, design research is relevant for educational practice (and therefore also for educational policy) as it aims to develop research-based solutions for complex problems in educational practice. Starting point for design research are educational problems for which no or only a few validated principles ('how to do' guidelines or heuristics) are available to structure and support the design and development activities[2]. Informed by prior research and review of relevant literature, researchers in collaboration with practitioners design and develop workable and effective interventions by carefully studying successive versions (or prototypes) of interventions in their target contexts, and in doing so they reflect on their research process with the purpose to produce design principles.

Many examples of the need for innovative interventions can be given at system level and institutional level. At system level, for example, one may want to develop a system for e-learning to serve a specific target group of students in higher education, and at the level of school or classroom one may want, for example, to address the question of what are effective methods for collaborative learning. See also Gustafson & Branch (2002) who developed a taxonomy of instructional development models based on a selected characteristics; they distinguish between models with a classroom orientation, product orientation and system orientation.

The research process in design research encompasses educational design processes. It is – like all systematic educational and instructional design processes - therefore cyclical in character: analysis, design, evaluation and revision activities are iterated until a satisfying balance between ideals ('the intended') and realization has been achieved.

[2] see also the chapter of Kelly in this book where he discusses when design research is appropriate.

This process can be illustrated in various ways. Just a few examples are presented here to show how different authors have visualized the research process.

Reeves (2006) depicts the design research approach as follows:

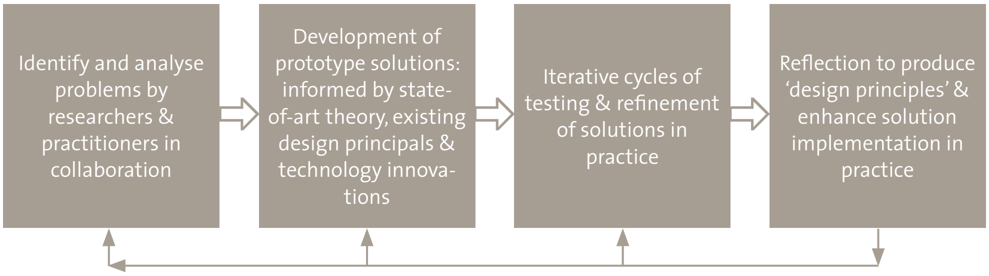


Figure 1: Refinement of Problems, Solutions, Methods, and Design Principles (Reeves, 2000, 2006)

McKenney (2001) illustrates in her study this cyclical process as follows:

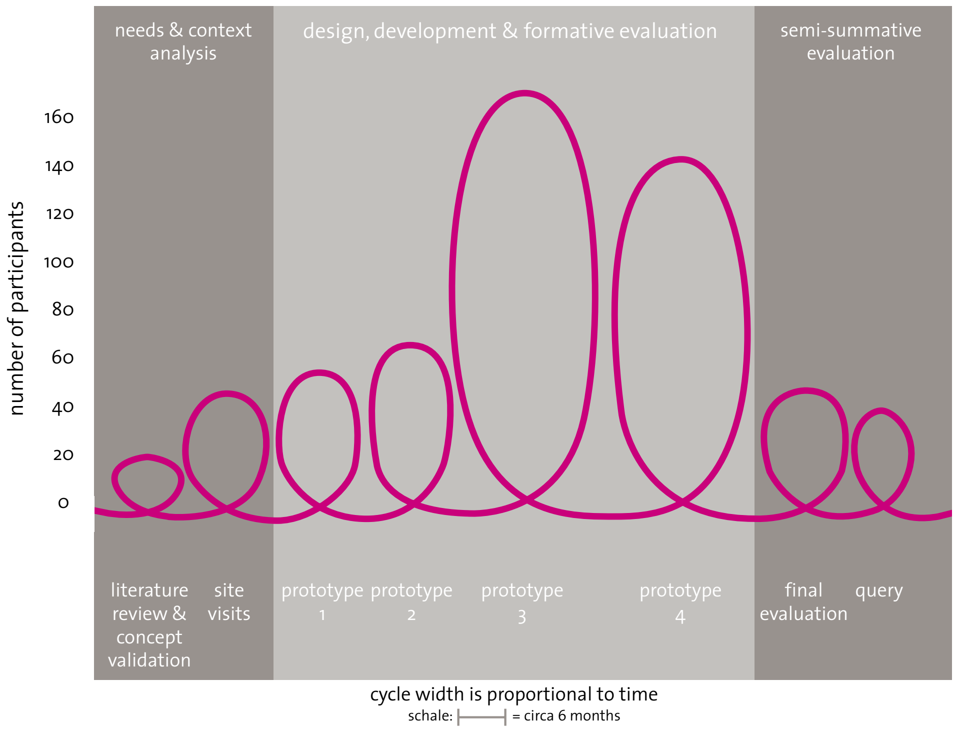


Figure 2: Display of the CASCADE-SEA study (McKenney, 2001)

The 'query' as the last phase in McKenney's display can be interpreted as the reflection box in the model of Reeves (Figure 1).
Another example is the Integrative Learning Design Framework that Bannan-Ritland presents in chapter 5 of this book (see also Bannan-Ritland, 2003).

Authors may vary in the details of how they picture design research, but they all agree that design research comprises of a number of stages or phases:

- *preliminary research:* needs and context analysis, review of literature, development of a conceptual or theoretical framework for the study
- *prototyping phase:* iterative design phase[3] consisting of iterations, each being a micro-cycle of research[4] with formative evaluation as the most important research activity aimed at improving and refining the intervention
- *assessment phase:* (semi-) summative evaluation to conclude whether the solution or intervention meets the pre-determined specifications. As also this phase often results in recommendations for improvement of the intervention, we call this phase semi-summative.

Throughout all these activities the researcher or research group will do *systematic reflection and documentation* to produce the theories or design principles (a concept taken from Van den Akker, 1999 – see also chapter 2) as the scientific yield from the research. One may state that this systematic reflection and documentation makes that systematic design and development of an intervention becomes design research.

Authors about design research also agree a number of characteristics of this type of research. These are summarized by Van den Akker et al. (2006: 5):

- *Interventionist:* the research aims at designing an intervention in a real world setting;
- *Iterative:* the research incorporates cycles of analysis, design and development, evaluation, and revision;
- *Involvement of practitioners:* active participation of practitioners in the various stages and activities of the research
- *Process oriented:* the focus is on understanding and improving interventions (a black box model of input – output measurement is avoided);
- *Utility oriented:* the merit of a design is measured, in part by its practicality for users in real contexts; and
- *Theory oriented:* the design is (at least partly) based on a conceptual framework and upon theoretical propositions, whilst the systematic evaluation of consecutive prototypes of the intervention contributes to theory building.

3) it is possible that the design/development component in a such a research project will not begin from scratch but with the evaluation of an existing intervention with the aim of identifying the need for improvement, which then is followed by re-design and a number of design cycles.

4) term taken from Bannan-Ritland, chapter 5

The features and characteristics of design research are nicely captured by Wademan (2005) in what he calls the Generic Design Research Model (Figure 3). His model clearly illustrates that the 'successive approximation of practical products' (what we call 'interventions') is going hand in hand with the 'successive approximation of theory' (which he also calls 'design principles').

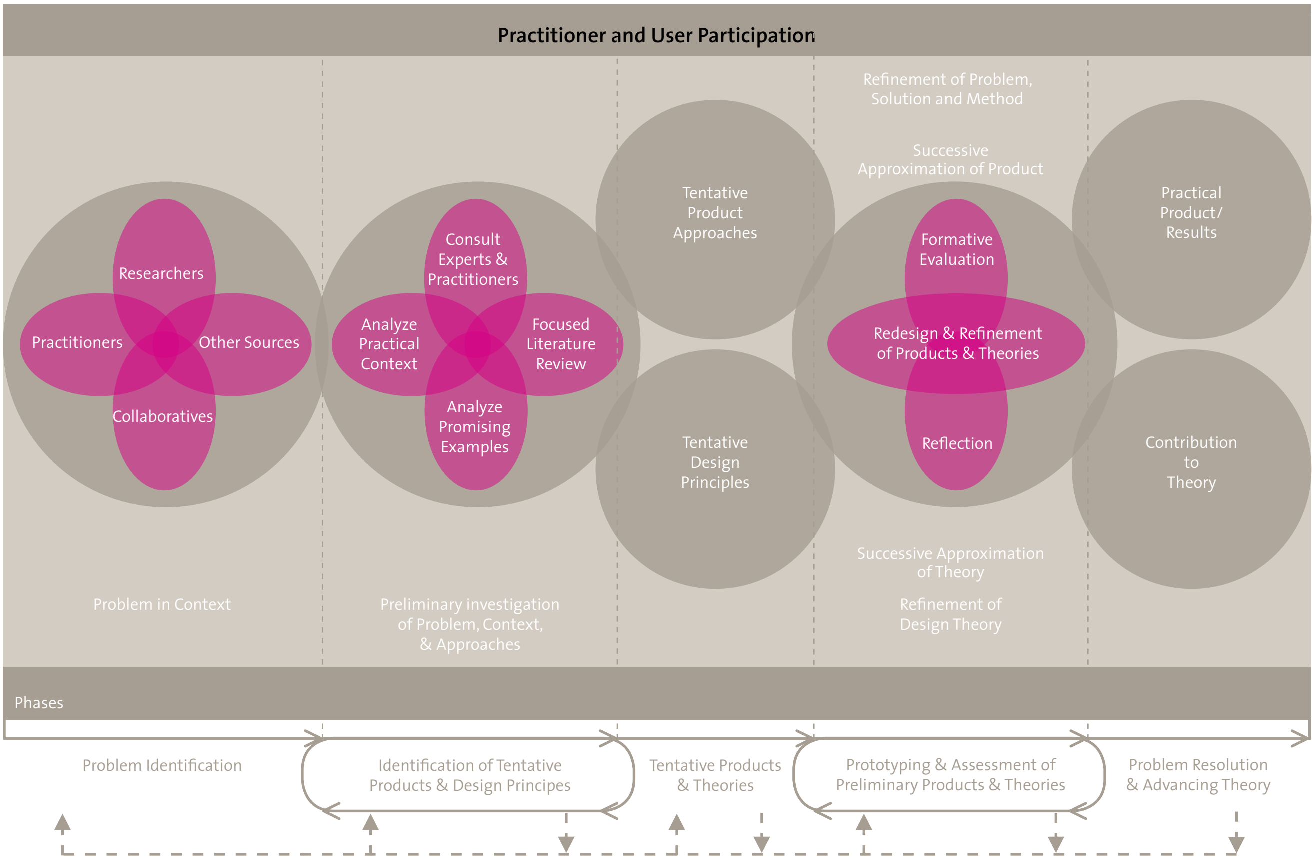


Figure 3: Generic Design Research Model (Wademan, 2005)

It is important to note that design research follows a holistic approach, and does not emphasize isolated variables. Van den Akker et al. (2006: 5) point to it that yet design researchers do focus on specific objects and processes (interventions) in specific contexts, but they try to study those as integral and meaningful phenomena. This context bound nature of much design research also explains why it usually does not strive towards context-free generalizations. If an effort to generalizing is made, then it is an analytical generalization (in contrast to statistical generalization where the researcher may generalize from sample to population). (See also the section 'outputs of design research')

A closer look at design research

As stated key characteristics of design research are that it is research focused on designing interventions in the real context of education or training (*interventionist* characteristic) combined with efforts to understand and improve interventions (*process orientation*), utilizing state of the art theories whilst the field testing and the evaluation of the consecutive prototypes should contribute to theory building *(theory orientation)*.
In this section we will have a look at what it means that research supports educational design processes, and reversely that educational design processes support research. This is followed by a brief discussion of the type of research question in design research. Possible outputs of design research will be discussed in the next section.

As we already stated, one of the aims of design research is designing and developing an intervention as an (innovative) solution to a complex problem, and therefore the starting point for design research are educational problems for which no or only a few validated principles ('how to do' guidelines) are available to structure and support the design and development activities.
On the other hand, design research is research and therefore the appropriate yield for design research (apart from a usable and effective intervention) is empirically founded theory, i.e. the challenge for design research is to capture and make explicit the implicit decisions associated with a design process, and to transform them into guidelines for addressing educational problems (see Edelson, 2006; 101; also Barab & Squire (2003), and many other authors). This aspect refers to the *theory orientation*, mentioned above as one of the characteristics of design research. Van den Akker (1999, 2006, also chapter 2), Reeves (2006; see figure 1) and Wademan (2005; see figure 3) use the concept of 'design principles' when they refer to the theoretical yields of design research, where others speak of new theories (e.g. Barab & Squire, 2003; Edelson, 2006).

However, it is not self-evident how the design of interventions may contribute to theory building. With reference to the generic model of Wademen (Figure 3) and the exemplary schemes of Reeves (2006) in Figure 1 and McKenney (2001) in Figure 2, one may state that the researcher (or better: the collective of researchers and practitioners) - based on analysis of the problem in context, and utilizing relevant, state-of-the-art theories – designs and develops (in an iterative way) the intervention with the aim that after a number of cycles the intended outcomes are realized, i.e. a satisfying solution to the problem identified. Each iteration or cycle is a micro-cycle of research, i.e. a step in the process of doing research and will include *systematic reflection* on the theoretical aspects or design principles in relationship to the status of the intervention, resulting in the end in design principles or theoretical statements.

In other words, in the end the researcher (or research group) will conclude about his intervention:

Given my context, if I do <intervention (theory based) > then I expect <intended outcomes>.

This can be displayed schematically as:

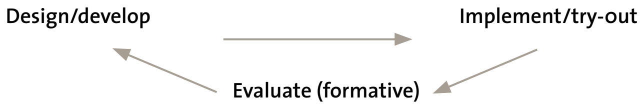
Two points are important in this scheme:

- the outcomes of the intervention are indicated as Y_1, Y_2, ..., Y_n , because often an intervention is designed to realize multiple outcomes (e.g. better achievement, improved student attitude, increased teacher satisfaction, etc).
- the intervention is presented as 'input → process', because designing a process (e.g. learning environment) has to take into account also the inputs necessary to make the process function (e.g. certain instructional learning materials, teacher development).

So in the end, the research group has not only at its disposal the intervention resulting in the desired outcomes, but also based on a systematic reflection and analysis of the data collected during this cyclical process an understanding of the 'how and why' of the functioning of the intervention in the particular context within it was developed. The design researcher will summarize this understanding of the 'how and why' of the intervention in one or more 'design principles' if we would use the terminology of Van den Akker (1999, 2006) and Reeves (2000, 2006). As other authors, e.g. Barak & Squire (2004) and Edelson (2006), use of 'theory' as the yield of design research, one may also speak of 'intervention theory' or 'design theory' (Wademan, 2005; Figure 3) as a second generic term to refer to the knowledge generated from this research endeavour (see below for specific examples).

design principles or intervention theory

In design research, interventions are developed in a *cyclical process* of successive prototypes:



A key idea is that when in a certain cycle the prototype of the intervention does not result in the desired outcomes, one may conclude that the design principles (or intervention theory) applied are not (yet) effective (or, in other words, that the intervention theory 'fails'). This has to result in a re-design or refinement of the intervention, which goes hand-in-hand with the refinement of the intervention theory or design theory.
When after a number of iterations the researcher (or research group) concludes that based on the analysis of the evaluation data the 'realized outcomes' are close enough to the 'intended outcomes' then he can be satisfied: the design principles appear to be effective. Or, in other words, the researcher (or research group) has developed a 'local' (intervention) theory (i.e. for the context in which he/she works): *in context Z the intervention X (with certain characteristics) leads to outcomes* $Y_1, Y_2, \ldots, Y_n$.

Two examples are given to illustrate this – rather abstract – phrasing of the yield of design research. The Design-Based Learning Research Collective (2003:5) state that "the design of innovations enables us to create leaning conditions that learning theory suggests are productive, but that are not commonly practiced or are not well understood" – in other words included in the innovations is knowledge about how to create conditions for learning.
The second example is taken from science education. Lijnse (1995:192) argues that design research (he calls it developmental research) is "a cyclic process of theoretical reflections, conceptual analysis, small-scale curriculum development, and classroom research of the interaction of teaching-learning processes. The final, empirically based description and justification of these interrelated processes and activities constitutes what we call a possible "didactical structure" for the topic under consideration." In other words, the local theory consists of a didactical structure for teaching-learning processes for a certain topic.

The research question in design/development research

By now it is clear that designing and developing an intervention is in itself not yet design research. But one may conduct a design/development project as a research project by employing rigorously social science research methodology. As the researcher is striving to find design principles (or an *intervention theory*) that are valid in a certain context, the research question can be phrased as:

what are the characteristics **of an <intervention X> for the purpose/outcome Y ($Y_1, Y_2, \ldots, Y_n$) in context Z**

Examples of research questions are:
(i) what are the characteristics of an effective in-service programme for mathematics teachers through which they develop the ability to apply student-centred pedagogical methods, and
(ii) what are the characteristics of an in-service arrangement that facilitates the implementation of MBL[5]-supported lesson activities in physics education (Tecle, 2003)?

Obviously, not all researchers are using this type of phrasing, but the wording of the main research question in design research always implies a search for characteristics. An example is: What is an adequate learning and teaching strategy for genetics in upper secondary biology education in order to cope with the main difficulties in learning and teaching genetics, and to promote the acquisition of a meaningful and coherent understanding of hereditary phenomena? (Knippels, 2002)

The outputs of design research

We already concluded that design research results in interventions (programs, products, processes) and in design principles or intervention theory. A third output of design research is professional development of the participants involved in the research. Each of these outputs is briefly discussed.

On design principles or intervention theory
Design research aims at producing knowledge about whether and why an intervention works in a certain context. In the previous section this type of output has been called design principles or intervention theory. Other authors use terms like domain specific theories (Gravemeijer & Cobb, 2006), design theory (Wademan, 2005; Figure 3), heuristics or just lessons learned (see Van den Akker et al. 2006). We will use the term *design principles* in the remaining of this paper.

Design principles are *heuristic statements* for which Van den Akker (1999) developed the following format:

> **"If you want to design intervention X for the purpose/function Y in context Z, then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R." (Van den Akker, 1999)**

5) MBL = Microcomputer Based Laboratory.

The heuristic principles are meant to support designers in their tasks, but cannot guarantee success - they are intended to assist (in other projects) in selecting and applying the most appropriate (substantive and procedural) knowledge for specific design and development tasks.

Substantive knowledge is knowledge about essential characteristics of an intervention and can be extracted (partly) from a resulting intervention itself. Procedural knowledge refers to the set of design activities that are considered most promising in developing an effective and workable intervention.

As knowledge is incorporated in interventions, it is profitable for design researchers in the early stage of their research to search for already available interventions that can be considered useful examples or sources of inspiration for the problem at stake. Careful analysis of such examples in combination with reviewing relevant literature) will generate ideas for the new design task.

The value of knowledge resulting from a design research project will strongly increase when it is justified by theoretical arguments, well-articulated in providing directions, and convincingly backed-up with empirical evidence about the impact of those principles. It is for this reason that authors (e.g. Van den Akker 1999, 2006; Reeves, 2000, 2006) state that the final stage of each design research project should consist of systematic reflection and documentation to produce design principles.

Generalizability in design research

Heuristic design principles will be additionally powerful if they have been validated in the successful design of more similar interventions in various contexts. Chances for such knowledge growth will increase when design research is conducted in the framework of research programs, because then projects can build upon one another.

Here we touch on the question to what extent design principles can be generalized from one context to others. It is in this context that Edelson (2006) states that design research should result in generalizable theory.

In design research, like in case studies and experimental studies, the findings cannot be generalized to a larger universe – there is no statistical generalization from sample to population, like can be the case in survey research. Yin (2003) points to it that in case studies and experimental studies, the investigator is striving to generalize a particular set of results to a broader theory. This is also the case in design research, the researcher should strive to generalize 'design principles' to some broader theory.

Yin (2003: 37) points to it that generalization is not automatic. Design principles must be tested through replications of the findings in a second, third or more cases in various contexts with the purpose that the same results should occur. Once such replications have been made, the results might be accepted for a much larger number of similar contexts, even though further replications have not been performed. This *replication logic* is the same that underlies the use of experiments and allows experimental scientists to generalize from one experiment 'to another': Yin (2003) calls this analytical generalizability. But a warning should be phrased here. Where design principles may have been supported by a number of replications, and a new context may be similar to the ones from which design principles have emerged, yet each context has unique characteristics that justifies that the design principles should be used as 'heuristic' statements: they provide guidance and direction, but do not give 'certainties'. It is in this context that Reeves (2006) cites Lee Cronbach one of the most influential researchers of the 20th century: *"When we give proper weight to local conditions, any generalization is a working hypothesis, not a conclusion."* (Cronbach, 1975: 125)

On interventions

Design research by its character aims to be practically relevant. It is initiated to design and develop innovative interventions to meet a need felt in a complex, practical situation for which no ready-made solutions or guidelines are available. Therefore design researchers aim at developing interventions (such as programs, teaching-learning strategies and materials, products and systems) that can be used in practice and are empirically underpinned solutions to the problems identified.

On professional development

One of the features of design research is the collaboration of researchers and practitioners. This collaboration increases the chance that the intervention will indeed become practical and relevant for the educational context which increases the probability for a successful implementation. But the participation of practitioners should also be seen as an important form of professional development. An extra spin-off may be that practitioners will develop an awareness of how research may contribute to improving their professional context.

Design research differentiation

Design research is conducted through a number of cycles of design and development resulting in the initial implementation of the intervention in a limited number of contexts. As stated above, design research has usually a number of stages or phases (see also Figures 1, 2 and 3):

- needs and content analysis
- prototyping phase (iterative cycles of design and formative evaluation)
- assessment phase (semi-summative evaluation)

Nieveen et al. (2006) suggest that design research that has resulted in a validated and effective intervention (as a solution for the problem under study), and in design principles can be followed by *effect studies* (not necessarily part of the same research project) with an emphasis on upscaling the intervention to a wider context, and in doing so aiming at design principles tested in a wider domain. Effect studies may range from small-scale learning experiments to large-scale comparative testing of impact (e.g. via randomized controlled trials).

A further differentiation in design studies is possible on the basis of variations in goals of design research viz *validation* studies versus *development* studies (see Van den Akker, Gravemeijer et al., 2006; chapters 5 and 10).

Validation studies have a focus on designing learning environments or trajectories with the purpose to develop and validate theories about the process of learning and how learning environments can be designed. Validation studies aim at advancing learning and instruction theories, such as (Gravemeijer & Cobb, 2006):
- micro-theories: at the level of instructional activities
- local instruction theories: at the level of instructional sequence;
- domain-specific instruction theories: at the level of pedagogical content knowledge.

In validation studies, researchers do not work in controlled (laboratory or simulated) settings, but they choose the natural setting of classroom as 'test beds' (although they tend to work with above-average number of teaching staff). Usually, the stages in validation studies are (Gravemeijer & Cobb, 2006):
- *environment preparation:* elaborating a preliminary instructional design based on an interpretative framework;
- *classroom experiment:* testing and improving the instructional design or local instructional theory and developing an understanding of how it works;
- *retrospective analysis:* studying the entire data set to contribute to the development of a local instructional theory and (improvement of) the interpretative framework.

DiSessa and Cobb (2004: 83) warn that "design research will not be particularly progressive in the long run if the motivation for conducting experiments is restricted to that of producing domain specific instructional theories". But the practical contribution lies in developing and implementing specific learning trajectories that were implemented to test the theoretical basis of the design. (Nieveen et al, 2006: 153)

Development studies aim towards design principles for developing innovative interventions that are relevant for educational practice. "Development studies integrate state-of-the-art knowledge from prior research in the design process and fine-tune educational innovations based on piloting in the field. ... By unpacking the design process, design principles that can inform future development and implementation decisions are derived." (Nieveen et al., 2006: 153). Two main types of design principles can be distinguished (Van den Akker, 1999):
1. procedural design principles: characteristics of the design approach;
2. substantive design principles: characteristics of the design (= intervention) itself.

Figure three summarizes the characteristics of a research cycle consisting of design studies and effect studies (as developed by Nieveen et al.; 2006: 155):

	Design research		Effectiveness research
	Validation studies	***Development studies***	
Design aim	To elaborate and validate theories	To solve educational problems	-
Quality focus of design	Theoretical quality of design	Practicality of intervention	Effectiveness of intervention
Knowledge claim/ scientific output	Domain-specific instruction theories	Broadly applicable design principles	Evidence of impact of intervention
Methodological emphasis	Iterative design with small scale testing in research setting	Iterative development with formative evaluation in various user settings	Large scale, comparative field experiments
Practical contribution	Specific learning trajectories for a specific classroom	Implemented interventions in several contexts/ classrooms	Evidence-based Change at large scale

Figure 4: Educational engineering research cycle (from Nieveen et al., 2006)

It is important to note that this distinction between validation and development studies is conceptually important, but that in practice many research project have aims that are a combination of solving problems in educational practice and elaborating and validating theories (design principles).

A further differentiation of design research is conceivable. For example, one can imagine that the dissemination and implementation of a particular program is supported by design research – the resulting intervention is the successfully disseminated and implemented program, whilst the systematic reflection and documentation of the process leads to a set of procedures and conditions for successful dissemination and implementation (the design principles).

As a final note, the differentiation between types of design research, such as validation studies versus development studies, serves mainly conceptual purposes. In practice, design researchers may combine the two orientations in their research. For example, starting from a complex and persistent problem in e.g. science education, the research group may decide to apply the design principles (local theories) resulting from other studies in their research. In doing so they are not only developing an intervention, but at the same time exploring the validity of design principles (theory) developed in another context for their own problem context.

How is design research conducted?
Design research is conducted iteratively as a collaboration of researchers and practitioners in a real-world setting. Only then the two principal outputs (design principles and empirically underpinned innovative interventions) can be realized. Doing research in such a setting is challenging and demands a careful research design. It is therefore important to reflect not only on the cyclical, iterative character of the systematic design of the intervention, but also – because it is research - to make explicit the tenets that form the foundation of this type of research (McKenney et al., 2006)

McKenney et al. (2006: 77) define three tenets to shape design research for the curriculum domain (but the tenets also apply to other domains):

- *Rigor* – for design research to be able to result in valid and reliable design principles, the research has to meet rigorous standards and apply the guiding principles for scientific research as mentioned by Shavelson & Towne (2002; mentioned above). Much literature is available to guide research in natural settings that offers support to issues like internal and external validity, reliability and utililization of the research.
- *Relevance:* Design research aims to be relevant for educational practice (and policy). A necessary condition for this is that the research group must have a good working knowledge of the target setting and be informed by research and developments activities taking place in natural settings (or test beds).
- *Collaboration:* for design research to be relevant for educational practice, the design and development activities must be conducted in collaboration with and not just for professionals from educational practice.

As explained in the beginning of this chapter, design research is cyclical and each iteration or cycle contributes to sharpening the aims and to bringing the interventions closer to the desired design outcomes and research outputs.
As is illustrated in Figures 1-3, design research usually goes through several stages which Nieveen et al. (2006: 154) phrase as follows (see also p. 15):

- *preliminary research:* thorough context and problem analysis along with the development of a conceptual framework based on literature review;
- *prototyping stage:* setting out design guidelines, optimizing prototypes of the intervention through cycles of design, formative evaluation, and revision – it is important to note that each cycle in the study is a piece of research in itself (i.e. having its research or evaluation question to be addressed with a proper research design);
- *assessment stage (summative evaluation):* often explores transferability and scaling, along with (usually small-scale evaluation of) effectiveness; and
- *systematic reflection and documentation:* this are continuous activities (as illustrated in Figure 3) that takes place during all cycles in the research – however, at the end the

researcher portrays the entire study to support retrospective analysis, followed by specification of design principles and articulation of their links to the conceptual framework.

It is beyond the scope of this chapter to discuss in detail how to perform these stages. But an exception is made for formative evaluation, because this is the key research activity in design research aimed at improving the quality of the consecutive prototypes of the intervention.

Formative evaluation in development research[6]

Based on prior work Nieveen (1999; see also Chapter 5) proposes four generic criteria for high quality interventions (see Table 1). She explains these criteria as follows: The components of the intervention should be based on state-of-the- art knowledge (*content validity*) and all components should be consistently linked to each other (*construct validity*). If the intervention meets these requirements it is considered to be valid. Another characteristic of high-quality interventions is that end-users (for instance the teachers and learners) consider the intervention to be usable and that it is easy for them to use the materials in a way that is largely compatible with the developers' intentions. If these conditions are met, we call these interventions *practical*. A third characteristic of high quality interventions is that they result in the desired outcomes, i.e. that the intervention is *effective*.

Criterion	
Relevance (also referred to as **content validity**)	There is a need for the intervention and its design is based on state-of-the-art (scientific) knowledge.
Consistency (also referred to as **construct validity**)	The intervention is 'logically' designed.
Practicality	The intervention is realistically usable in the settings for which it has been designed and developed.
Effectiveness	Using the intervention results in desired outcomes.

Table 1: Criteria for high quality interventions (from Nieveen, 1999; Chapter 5)

Given the character of design research, these four criteria may get different emphasis in different stages of the research as is illustrated by Figure 5. For example, during the preliminary research where the emphasis is on analyzing the problem and reviewing the literature, the criterion of relevance (content validity) is the most dominant, with some attention for consistency (construct validity) and practicality, whilst in that state no attention is yet given to effectiveness. On the other hand, in the prototyping stage much

[6] See also Nieveen's chapter 5 in this book in which she discusses how to do the formative evaluation in design research

attention has to be paid in the formative evaluation to the criterion of practicality, whilst effectiveness will become increasingly important in later iterations. Finally, in assessment stage of summative evaluation, the focus will be on practicality and effectiveness (see Figure 5, and Figure 2 for the stages).

	Stage	Criteria	Short description of activities
1	Preliminary research	Emphasis mainly on *content validity*, not much on *consistency* and *practicality*	Review of the literature and of (passed and/or present) projects addressing questions similar to the ones in this study. This results in (guidelines for) a framework and first blueprint for the intervention.
2	Prototyping stage	Initially: *consistency (construct validity)* and *practicality*. Later on mainly *practicality* and gradually attention for *efficiency*.	Development of a sequence of prototypes that will be tried out and revised on the basis of formative evaluations. Early prototypes can be just paper-based for which the formative evaluation takes place via expert judgments.
3	Assessment phase	*practicality* and *efficiency*	Evaluate whether target users can work with intervention (practicality) and are willing to apply it in their teaching (relevance & sustainability). Also whether the intervention is effective.

Figure 5: Evaluation criteria related to stages in design research

Formative evaluation takes place in all phases and iterative cycles of design research. As illustrated by Figure 5, formative evaluation serves different functions, or - in other words - is aimed at different criteria (or combinations of these) in the various development cycles, each being a micro-cycle of research with its specific research/evaluation question and related research/evaluation design. One may say that formative evaluation has various layers in a design research project as is illustrated in Figure 6, taken from Tessmer (1993): from more informal in the early stages of a project (self-evaluation, one-to-one evaluation, expert review) to small group evaluation aimed at testing the practicality and effectiveness, to a full field test (if applicable). The research/evaluation design for each cycle should reflect the specific focus and character of the cycle – see Chapter 5 by Nieveen for more details.

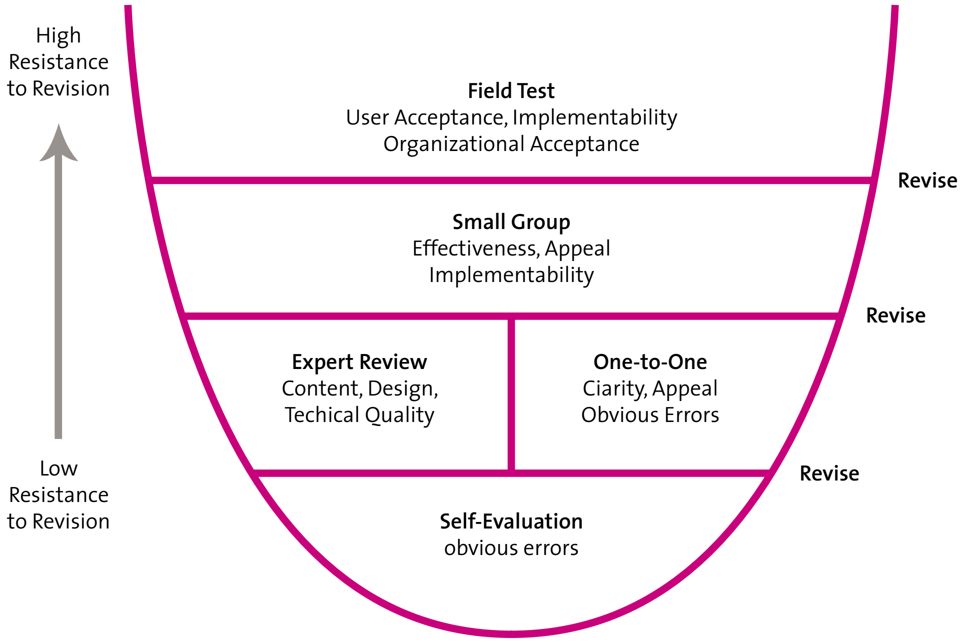


Figure 6: Layers of formative evaluation (taken from Tessmer, 1993)

Figure 6 also illustrates that many possible methods of formative evaluation can be chosen, such as[7]

- expert review and/or focus groups (important to consider 'experts in what')
- self-evaluation or screening (using check list of important characteristics or design specifications)
- one-to-one evaluation or walk through (with representative of target audience)
- small group or micro-evaluation
- field test or try-out

Design researchers should choose for each phase and for each prototype formative evaluation approaches that are suitable for the purpose of that particular stage of the research.

Design research has to meet criteria for good research. It is therefore important that for each development cycle the researcher (or research group) applies the methodological 'rules' for doing research, i.e. for identifying the target audience and sampling, for instrument development and apply triangulation to obtain good quality information. But

[7] see also Chapter 5 by Nieveen

given the layers of formative evaluation in design research, in the early cycles of development the evaluation design can be less rigorous than in later phases.
Figure 7 adapted from Nieveen (1999) presents an example that illustrates how various formative evaluation methods are used for the respective prototypes in a project aimed at developing a computer assisted support system for curriculum developers.

		prelim comp. based	paper-based		computer-based versions		final version	
		Users (n=5)	experts (n=3)	users (n=5)	experts (n=6)	users (n=4)	users (n=4)	users (n=17)
Validity	content *)		√ ea		√ ea			
	interface				√ ea			
Practicality	content	√ wt		√ wt	√ ea	√ me	√ to	√ ft
	interface	√ wt		√ wt	√ ea	√ me	√ to	√ ft
Effectiveness	entire system						√ to	√ ft

*): Content refers to the content of the support system

√ = primary attention of prototype and of formative evaluation

Methods of formative evaluation: me = micro evaluation; wt = walk through; ea = expert appraisal; ft = field trial; to = try-out

Figure 7: Focus of design and formative evaluation of the prototypes for computer assisted support system for curriculum development (adapted from Nieveen, 1999)

A final note on the criteria of practicality and effectiveness. It may occur in certain studies that the researcher (or research collaborative) cannot do a final field trial of the intervention with the full (or a sample of the) target group, but has to restrict himself to expert appraisal and/or micro-evaluation of the final prototype of the intervention. It is obvious that in such a situation the *actual practicality* and the *actual effectiveness* of the intervention cannot be demonstrated, but only conclusions about the *expected practicality* and the *expected effectiveness* can be drawn. More evaluation will then be needed to demonstrate the *actual practicality* and the *actual effectiveness*.
This can be illustrated with an example adapted from Mafumiko (2006) who conducted design research to investigate whether micro–scale experimentation can contribute to improving the chemistry curriculum in Tanzania. His research design has been summarized in Figure 8.

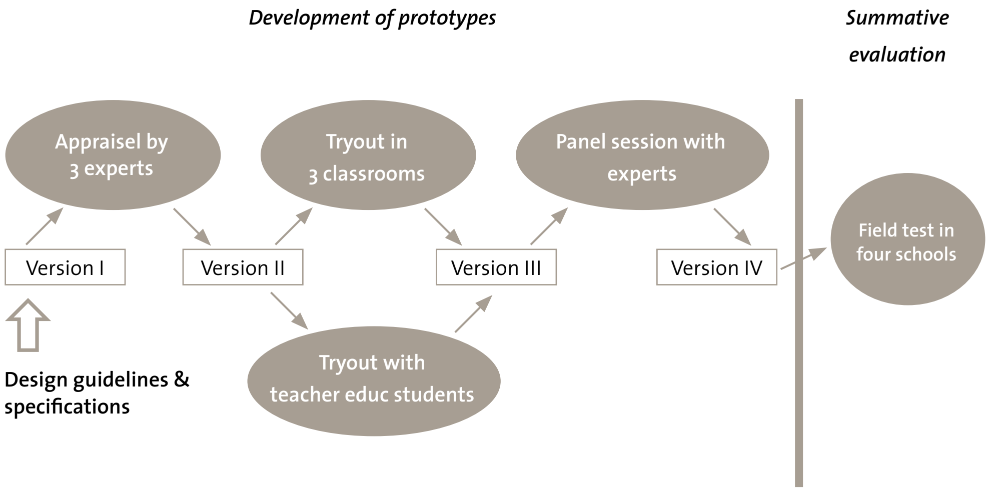


Figure 8: Example of research research design (adapted from Mafumiko, 2006)

Suppose a researcher would restrict himself to the development of prototypes of the intervention as illustrated in Figure 8, and does not plan to investigate whether Version IV works in the target context. In such a situation the most he can conclude is whether his intervention is expected to be practical and effective for the target context. Only when he would conduct a field test, he will be in the position to decide upon actual practicality and actual effectiveness (which is what Mafumiko did).

Design research dilemmas

Design research is conducted in close collaboration with educational practice. Not only the problem addressed is situated in educational practice, but a key feature of this research is that educational practitioners are actively involved, often as members of the research team. This leads to a number of challenges that are typical for this type of research. McKenney et al. (2006: 83,84) have discussed some of these and provide suggestions for how to address them. Their points are briefly summarized here.

1. **the researcher is designer and often also evaluator and implementer.**

Several measures can be taken to compensate for this potential conflict of interest:
- make research open to professional scrutiny and critique by people outside the project
- the researcher applies the following rule of thumb: shift from a dominance of 'creative designer' perspective in the early stage, *towards* the 'critical researcher' perspective in later stages (this is reflected in Tessmer's layers of formative evaluation, Figure 6)

- have a good quality of research design, e.g.
    - *strong chain of reasoning* (Krathwohl, 1998) - the metaphor expresses the idea that each part of the research design is equally important
    - *triangulation* – to increase the quality of data and of analysis triangulation of data sources and data collection methods should be applied, as well as investigator triangulation to avoid the influence of any specific researcher (see e.g. Denscombe, 2007;136)
    - *empirical testing* of both the usability and the effectiveness of the intervention
    - *systematic documentation, analysis* and *reflection* of the design, development, evaluation and implementation process and their results
    - have attention for validity and reliability of data and instruments
    - apply a variety of methods and tactics: e.g. use practitioners and other researchers as 'critical friends'; use multiple observers/raters and calculate inter-observer/rater reliability, etc.

2. real-world settings bring real-world complications

Design research is conducted in real-world settings because it addresses complex problems in educational practice. One of the problems is that the researcher can be a 'cultural stranger' (Thijs, 1999) in the setting of the research and that participants (e.g. principals, teachers not involved in the research, etc) are hesitant to be completely open to a researcher coming from the outside.

McKenney et al. (2006: 84) points to the importance of collaboration and mutual beneficial activities to gain participants' trust and thorough understanding of the context (i.e. insider perspective). On the other hand, they also point to the advantages to be an outsider as this may allow the researcher to develop a degree of objectivity and "freedom (or forgiveness) for honesty that is not permitted to those within a particular group" (o.c. 85)

3. adaptability

Design research is cyclical and takes place in real-world settings. Each cycle has to take the findings of the previous ones into account. So on the one hand the research design has to change (or develop) from one cycle to the other, whilst on the other hand an ever-changing research design can be weak. In this context, McKenney et al. (2006: 84) refer to the notion of evolutionary planning, i.e. "a planning framework that is responsive to field data and experiences as acceptable moments during the course of the study". This is already alluded to in the discussion of formative evaluation (see Figure 6 from Tessmer and the example taken from Nieveen, 1999).

The need for adaptability pertains also to the role of the researcher. According to Van den Akker (2005, in McKenney et al., 2006), the synergy between research and practice can be maximized when researchers demonstrate adaptability by:

(i) being prepared, where desirable, to take on the additional role of designer, advisor, and facilitator, without losing sight of their primary role as researcher,
(ii) being tolerant with regard to the often unavoidably blurred role distinctions and remaining open to adjustments in the research design if project process so dictates,
(iii) allowing the study to be influenced, in part, by the needs and wishes of the partners, during what is usually a long-term collaborative relationship.

Such adaptability requires strong organizational and communicative capabilities on behalf of the researcher, as well as sound understanding the research process so that careful changes and choices that maximize value and minimize threats to quality are made. (McKenney et al., 2006: 84).

To address the challenges mentioned, McKenney et al. (2006: 85, 86) present a few *guidelines for conducting design research* that may help researchers monitoring the scientific character of his/her research:

- have an explicit conceptual framework (based on review of literature, interviews of experts, studying other interventions)
- develop congruent study design, i.e. apply a strong chain of reasoning with each cycle having its research design
- use triangulation (of data source, data type, method, evaluator and theory) to enhance the reliability and internal validity of the findings
- apply both inductive and deductive data analysis
- use full, context-rich descriptions of the context, design decisions and research results
- member check, i.e. take data and interpretations back to the source to increase the internal validity of findings.

It is beyond the scope of this paper to elaborate on these guidelines further – see McKenney et al. (2006; 85, 86) and research methodology books.

Concluding remarks

In the field of education there is much need for research relevant for educational practice. We have argued that for complex practical problems and for research question(s) calling for the design and development of an intervention design research is the appropriate research approach.

Given its focus on practical problems and its nature of conducting the research in a real-world setting with active involvement of practitioners, design research may look like action research. So one may wonder how design research is related to action research. Indeed, action research is also dealing with real-world problems, aiming at improving practice, cyclical in nature and participative (Denscombe, 2007), but the essential difference is that action research is not aimed at generating design principles – it has a particular niche among professionals who want to use research to improve their practices (o.c.: 122).

We discussed how design researchers should strive for generalizable design principles in the meaning of generalizing to a broader theory. When design research is conducted within the framework of a program of research addressing fundamental problems in educational practice, it will result in a specific body of knowledge, viz substantive and procedural design principles that may contribute to improve education. On the other hand many questions are still to be addressed as there are many types of practical problems and therefore many types of research goals for which design research may be the best approach (e.g., Reeves (2000) mentions six different types of goals).

Van den Akker, Gravemeijer, McKenney and Nieveen (2006) report the presentations and discussions at a seminar dedicated to educational design research. Their book points - next to discussing a number of approaches to design research by Gravemeijer and Cobb (2006), Reeves (2006) and McKenney et al. (2006) - to issues like assessing the quality of design research proposals (chapters by Phillips, 2006, and by Edelson, 2006) and the quality of design research (chapter by Kelly, 2006) which need further reflection and elaboration.

Finally, a number of research reports and dissertations have been published which are exemplary for how design research can be conducted (see chapter 6 for examples). But for design research to mature further more research projects in a variety of contexts should not only be conducted, but also reported and discussed in research journals and at conferences.

Our hope is that the community of educational technologists in China will embark on this research endeavor and will actively contribute to the further development of educational design research.

Acknowledgement: *in preparing this chapter, much use has been made of Van den Akker, Gravemeijer, McKenney and Nieveen (2006).*

References

Bannan-Ritland, B. (2003). The Role of Design in Research: The Integrative Learning Design Framework *Educational Researcher, 32* (1), 21-24.

Barab, S. & Squire, K. (2004). Design-based research: putting a stake in the ground. *Journal of the Learning Sciences, 13* (1), 1-14.

Brown, A.L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of The Learning Sciences, 2* (2), 141-178.

Cronbach, L.J. (1975). Beyond the two disciplines of scientific psychology. *American Psychologist, 30* (2), 116-27.

Denscombe, M. (2007, 3rd ed)). *The good research guide for small-scale social research projects.* Buckingham (UK): Open University Press.

Design-Based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32* (1), 5-8.

diSessa, A.A. & Cobb, P. (2004). Ontological innovation and the role of theory in design experiments. *Educational Researcher, 32* (1), 77-103.

Edelson, D.C. (2006). Balancing innovation and risk: assessing design research proposals. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research.* London: Routledge, 100-106.

Gravemeijer, K. & Cobb, P. (2006). Design research from a learning design perspective. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research.* London: Routledge, 17-51.

Gustafson, K.L. & Branch, R.M. (2002). *Survey of instructional development models* (4th ed). Syracuse (NY, USA): ERIC Clearinghouse on Information & Technology.

Kelly, A.E. (2006). Quality criteria for design research: evidence and commitments. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research.* London: Routledge, 107-118.

Knippels, M.C.P.J. (2002). *Coping with the abstract and complex nature of genetics in biology education.* Utrecht (The Netherlands): University of Utrecht – CD- Bèta Press.

Krathwohl, D.R. (1998, 2nd ed). *Methods of Educational and Social Science Research: An integrated approach.* New York: Longman

Lijnse, P.L. (1995). “Developmental Research” as a way to an empirically based “Didactical Structure” of Science. *Science Education, 29* (2), 189-199.

Mafumiko, Fidelice Simbagungile Mbaruku (2006). *Micro-scale experimentation as a catalyst for improving the chemistry curriculum in Tanzania.* Doctoral thesis. Enschede (The Netherlands) University of Twente. Available from: http://purl.org/utwente/55448

McKenney, S. (2001). *Computer-based support for science education materials developers in Africa: exploring potentials.* Doctoral dissertation. Enschede: University of Twente.

McKenney, S., Nieveen, N. & Van den Akker, J. (2006). Design research from a curriculum perspective. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge, 62-90.

Nieveen, N. (1999). Prototyping to reach product quality. In J. van den Akker, R.M. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds), *Design approaches and tools in education and training.* Boston: Kluwer Academic, 125-136.

Nieveen, N., McKenney, S. & Van den Akker, J. (2006). Educational design research: the value of variety. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge,151-158.

Phillips, D.C. (2006). Assessing the quality of design research proposals: some philosophical perspectives. In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge, 93-99.

Reeves, T. (2000). Enhancing the worth of instructional technology research through "design experiments" and other developmental strategies. *AERA*. AERA.Retrieved Oct. 20, 2006 from http://it.coe.uga.edu/~treeves/AERA2000Reeves.pdf

Reeves, T.C. (2006). Design research from a technology perspective. . In: Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge, 52-66.

Shavelson, R. & Towne, L. (2002). *Scientific research in education*. Washington DC: National Academic Press (website: http://books.nap.edu/books)

Tecle, A.T. (2006). *The potential of a professional development scenario for supporting biology teachers in Eritrea*. Doctoral dissertation. Enschede (The Netherlands): University of Twente.

Tessmer, M. (1993). *Planning and conducting formative evaluations.* London: Kogan Page.

Thijs, A. (1999). *Supporting science curriculum reform in Botswana: The potential of peer coaching*. Doctoral dissertation. Enschede: University of Twente.

Van den Akker, J. (1999). Principles and Methods of Development Research. In J. van den Akker, R.M. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds), *Design approaches and tools in education and training.* Boston: Kluwer Academic, 1-14.

Van den Akker, J. (2005). Hoe kan samenwerking leiden tot meer succes en wijsheid in onderwijsontwikkeling? [How can collaboration lead to more success and wisdom in education development?]. *Pedagogische Studiën, 82*(4), 343-7.

Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge. ISBN10: 0-415-39635-2 (pbk)

Wademan, M. (2005). *Utilizing Development Research to Guide People Capability Maturity Model Adoption Considerations.* Unpublished doctoral dissertation, Syracuse University (New York, USA).

Yin, R.K. (2003, 3ed ed). *Case study research: design and methods.* Newbury Park (CA, USA): Sage – Applied Social Research Methods Series, volume 5.

2. Curriculum Design Research

Jan van den Akker

Introduction

The title of this chapter *(Curriculum Design Research)* intentionally combines two fields: 'curriculum design' and 'design research'. It symbolizes the aim of this text to discuss the function and forms of design research from a curricular perspective. In particular, it focuses on how design research can increase the quality of curriculum design and development. Also, it illustrates how the relevance of educational research - a widely debated issue - can benefit from a connection to curriculum policies and practices.

Given this aim it helps to have a number of basic concepts and analytical perspectives available that can structure curricular deliberations and reduce the complexity of curriculum tasks. Thus my initial focus in this chapter (building on van den Akker, 2003) is on summarizing a set of concepts and perspectives that help to increase the transparency and balance of curriculum analysis, development and discourse. Then, the focus will shift towards (curriculum) design research (building on van den Akker, 1999, 2006, and on van den Akker, Gravemeijer, McKenney and Nieveen, 2006). First, I will sketch the potential and characteristics of design research in addressing complex curriculum challenges. Second, I will address a number of methodological issues. Finally, I will pay attention to a classic problem in all educational research: generalization of findings.

Curriculum, what's in a name?

When there is a myriad of definitions of a concept in the literature (as with curriculum), it is often difficult to keep a clear focus on its essence. In those cases it often helps to search for the etymological origin of the concept. The Latin word 'curriculum' (related to the verb 'currere' i.e. running) refers to a 'course' or 'track' to be followed. In the context of education, where learning is the central activity, the most obvious interpretation of the word curriculum is then to view it as a course, trajectory, or '*plan for learning*' (cf. Taba, 1962). This very short definition (reflected in related terms in many languages) limits itself to the core of all other definitions, permitting all sorts of elaborations for specific educational levels, contexts, and representations. Obviously, contextual specification is always needed in curriculum conversations to clarify the perspective.

Given this simple definition, a differentiation between various levels of the curriculum has proven to be very useful when talking about curricular activities (policy-making; design and development; evaluation and implementation). The next distinction appears to be helpful:

- International/comparative (or *supra* level)
- System/society/nation/state (or *macro*) level (e.g. national syllabi or core objectives)

- School/institution (or *meso*) level (e.g. school-specific curriculum)
- Classroom (or *micro*) level (e.g. textbooks, instructional materials)
- Individual/personal (or *nano*) level.

The supra level usually refers to international debates or agreements on aims and quality of education, sometimes fuelled by outcomes of internationally comparative studies (cf. PISA or TIMSS[1]). Curriculum development at the supra level is usually of a 'generic' nature, while 'site-specific' approaches are more applicable for the levels closer to school and classroom practice. Moreover, the process of curriculum development can be seen as narrow (developing a specific curricular product) or broad (a long term, ongoing process of curriculum improvement, often including many related aspects of educational change, e.g teacher education, school development, testing and examinations). In order to understand problems of curriculum decision-making and enactment, a broader description of curriculum development is often most appropriate: usually a long and cyclic process with many stakeholders and participants; in which motives and needs for changing the curriculum are formulated; ideas are specified in programs and materials; and efforts are made to realize the intended changes in practice.

Moreover, curricula can be represented in various forms. Clarification of those forms is especially useful when trying to understand the problematic efforts to change the curriculum. A common broad distinction is between the three levels of the 'intended', 'implemented', and 'attained' curriculum. A more refined typology (van den Akker, 2003) is outlined in box 1.

INTENDED	***Ideal***	Vision (rationale or basic philosophy underlying a curriculum)
	Formal/Written	Intentions as specified in curriculum documents and/or materials
IMPLEMENTED	***Perceived***	Curriculum as interpreted by its users (especially teachers)
	Operational	Actual process of teaching and learning (also: curriculum-in-action)
ATTAINED	***Experiential***	Learning experiences as perceived by learners
	Learned	Resulting learning outcomes of learners

Box 1: Typology of curriculum representations

Traditionally, the intended domain refers predominantly to the influence of curriculum policy makers and curriculum developers (in various roles), the implemented curriculum

[1] PISA is the OECD Programme for International Student Assessment, a survey every three years of the 15-year-olds. TIMSS is the Trends In Mathematics and Sciences Study, conducted every 4 years by the International Association for the Evaluation of Educational Achievement (IEA) in primary and secondary education.

relates especially to the world of schools and teachers, and the attained curriculum has to do with the students.

Besides this differentiation in representations, curriculum problems can be approached from various analytical angles. For example, Goodlad (1994) distinguishes the following three different perspectives:

- *substantive*, focusing on the classical curriculum question about what knowledge is of most worth for inclusion in teaching and learning;
- *technical-professional*, referring to how to address tasks of curriculum development;
- *socio-political*, referring to curriculum decision-making processes, where values and interests of different individual and agencies are at stake.

Some might argue that this list is too limited as it refers especially to curriculum issues for 'traditional' planning for learning in schools, and does not include the more 'critical' perspectives that are amply present in curriculum theory literature (e.g. Pinar, Reynolds, Slattery & Taubman, 1995). However, from a primary interest in curriculum improvement, the three perspectives seem useful and appropriate.

The vulnerable curriculum spider web

One of the major challenges for curriculum improvement is creating balance and consistency between the various components of a curriculum (i.e. plan for learning). What are those components? The relatively simple curriculum definition by Walker (2003) includes three major planning elements: content, purpose and organization of learning. However, curriculum design and implementation problems have taught us that it is wise to pay explicit attention to a more elaborated list of components. Elaborating on various typologies, we have come to adhere to a framework (see Box 2) of ten components that address ten specific questions about the planning of student learning.

Rationale or Vision	Why are they learning?
Aims & Objectves	Toward which goals are they learning?
Content	What are they learning?
Learning activities	How are they learning?
Teacher role	How is the teacher facilitating learning?
Materials & Resources	With what are they learning?
Grouping	With whom are they learning?
Location	Where are they learning?
Time	When are they learning?
Assessment	How to measure how far learning has progressed?

Box 2: Curriculum components

The 'rationale' (referring to overall principles or central mission of the plan) serves as major orientation point, and the nine other components are ideally linked to that rationale and preferably also consistent with each other. For each of the components many sub-questions are possible. Not only on substantive issues (see the next section), but, for example, also on 'organizational' aspects as:

- Grouping:
  - How are students allocated to various learning trajectories?
  - Are students learning individually, in small groups, or whole-class?
- Location:
  - Are students learning in class, in the library, at home, or elsewhere?
  - What are the social/physical characteristics of the learning environment?
- Time:
  - How much time is available for various subject matter domains?
  - How much time can be spent on specific learning tasks?

The relevance of these components varies across the previously mentioned curriculum levels (supra, macro, meso, micro, nano) and representations. A few examples may illustrate this.

- Curriculum documents at the macro-level will usually focus on the first three components (rationale, aims & objectives, content; often in rather broad terms), sometimes accompanied by an outline of time allocations for various subject matter domains.
- When one takes the operational curriculum in schools and classrooms in mind, all ten components have to be coherently addressed to expect successful implementation and continuation.
- The components of learning activities, teacher role, and materials & resources are at the core of the micro-curriculum in the classroom.
- The component of assessment deserves separate attention at all levels and representations since careful alignment between assessment and the rest of the curriculum appears to be critical for successful curriculum change.

Our preferential visualization of the ten components is to arrange them as a spider web (Figure 1), not only illustrating its many interconnections, but also underlining its vulnerability. Thus, although the emphasis of curriculum design on specific components may vary over time, eventually some kind of alignment has to occur to maintain coherence. A striking example is the trend toward integration of ICT in the curriculum, with usually initial attention to changes in materials and resources. Many implementation studies have exemplified the need for a more comprehensive approach and systematic attention to the other components before one can expect robust changes.

The spider web also illustrates a familiar expression: every chain is as strong as its weakest link. That seems another very appropriate metaphor for a curriculum, pointing to the complexity of efforts to improve the curriculum in a balanced, consistent and sustainable manner.

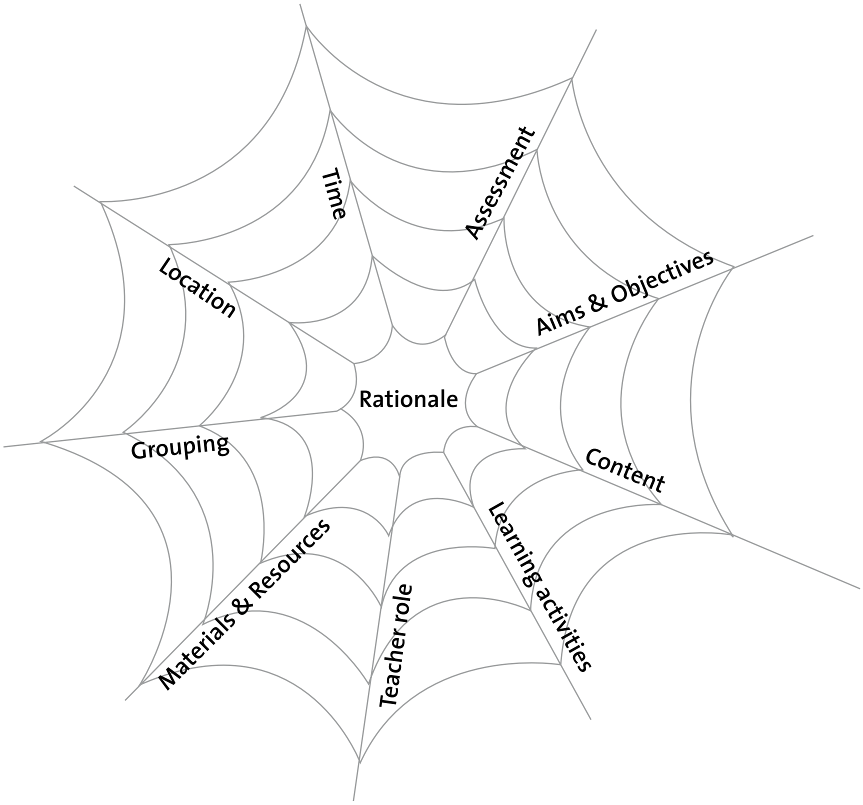


Figure 1: Curricular spider web

Perspectives on substantive choices

A classic approach to the eternal curriculum question of what to include in the curriculum (or even more difficult as well as urgent: what to exclude from it) is to search for a balance between three major sources or orientations for selection and priority setting:

- Knowledge: what is the academic and cultural heritage that seems essential for learning and future development?
- Society: which problems and issues seem relevant for inclusion from the perspective of societal trends and needs?
- Learner: which elements seem of vital importance for learning from the personal and educational needs and interests of the learners themselves?

Answers to these questions usually constitute the rationale of a curriculum. Inevitably, choices have to be made, usually involving compromises between the various orientations (and their respective proponents and pressure groups). Oftentimes, efforts fail to arrive at generally acceptable, clear and practical solutions. The result of adding up all kinds of wishes is that curricula tend to get overloaded and fragmented. Implementation of such incoherent curricula eventually tends to lead to student frustrations, failure, and dropout. How to create a better curriculum balance? Easy answers are not available, but a few alternatives seem to have some promise. First, in view of the multitude of (academic) knowledge claims, it sometimes helps to reduce the big number of separate subject domains to a more limited number of broader learning areas, combined with sharper priorities in aims for learning (focusing on basic concepts and skills).
Second, referring to the avalanche of societal claims, more interaction between learning inside and outside the school may reduce the burden. However, the most effective response is probably to be more selective in reacting to all sorts of societal problems. As Cuban (1992) phrased it clearly: schools should not feel obliged to scratch the back of society every time society has an itch.
And third, about the learners' perspective: worldwide, many interesting efforts are ongoing to make learning more challenging and intrinsically motivating by moving from traditional, teacher- and textbook-dominated instruction towards more meaningful, activity-based and autonomous learning approaches.

Development strategies

To sketch curriculum development as a problematic domain is actually an understatement. From a socio-political stance, it seems often more appropriate to describe it as a war zone, full of conflicts and battlefields between stakeholders with different values and interests. Problems manifest themselves in the (sometimes spectacular and persistent) gaps between the intended curriculum (as expressed in policy rhetoric), the implemented curriculum (real life in school and classroom practices), and the attained curriculum (as manifested in learner experiences and outcomes). A typical consequence of those tensions is that various frustrated groups of participants blame each other for the failure of reform or improvement activities. Although such blaming games often seem rather unproductive, there are some serious critical remarks to be made on many curriculum development approaches worldwide. First of all, many curriculum reform efforts can be characterized by overly big innovation ambitions (especially of politicians) within unrealistically short timelines and with very limited investment in people, especially teachers. Second, oftentimes there is a lack of coherence between the intended curriculum changes with other system components (especially teacher education and assessment/examination programs). And

last but not least, timely and authentic involvement of all relevant stakeholders is often neglected.
From a strategic point of view, the literature has offered us many (technical-professional) models and strategies for curriculum development. Three prominent approaches are Tyler's rational-linear approach, Walker's deliberative approach, and Eisner's artistic approach. As it does not fit within the purpose of this chapter to explain those models in particular, the reader is referred to educative texts as from Marsh and Willis (2003).
Obviously, the context and nature of the curriculum development task at hand will determine to a large extent what kind of strategy is indicated. It is noteworthy that we are beginning to see more blended approaches that integrate various trends and characteristics of recent design and development approaches in the field of education and training (for an overview and a series of examples: see van den Akker, Branch, Gustafson, Nieveen & Plomp, 1999). Some key characteristics:

- *Pragmatism:* Recognition that there is not a single perspective, overarching rationale or higher authority that can resolve all dilemmas for curriculum choices to be made. The practical context and its users are in the forefront of curriculum design and enactment.
- *Prototyping:* Evolutionary prototyping of curricular products and their subsequent representations in practice is viewed as more productive than quasi-rational and linear development approaches. Gradual, iterative approximation of curricular dreams into realities may prevent paralysis and frustrations. Formative evaluation of tentative, subsequent curriculum versions is essential to such curriculum improvement approaches.
- *Communication:* A communicative-relational style is desirable in order to arrive at the inevitable compromises between stakeholders with various roles and interests and to create external consistency between all parties involved.
- *Professional development:* In order to improve chances on successful implementation, there is a trend towards more integration of curriculum change and professional learning and development of all individuals and organizations involved.

Design or development(al) research is a research approach that incorporates some of these characteristics, and it becomes even more promising by adding the element of knowledge growth to it (van den Akker, 1999). Such research can strengthen the knowledge base in the form of design principles that offer heuristic advice to curriculum development teams, when (more than in common development practices) deliberate attention is paid to theoretical embedding of design issues and empirical evidence is offered about the practicality and effectiveness of the curricular interventions in real user settings.
However, there are several persistent dilemmas for curriculum development that can not easily be resolved, let alone through generic strategies. For example: how to combine aspirations for large-scale curriculum change and system accountability with the need for

local variations and ownership? The tension between these conflicting wishes can be somewhat reduced when one avoids the all too common 'one size fits all' approach. More adaptive and flexible strategies will avoid detailed elaboration and over-specification of central curriculum frameworks. In-stead, they offer substantial options and flexibility to schools, teachers, and learners. Although struggles about priorities in aims and content will remain inevitable, the principle of 'less is more' should be pursued. However, what is incorporated in a core curriculum should be clearly reflected in examination and assessment approaches.
The 'enactment' perspective (teachers and learners together create their own curriculum realities) is increasingly replacing the 'fidelity' perspective on implementation (teachers faithfully follow curricular prescriptions from external sources). This trend puts even more emphasis on teachers as key people in curriculum change. Both individual as well as team learning is essential (Fullan, 2001). Teachers need to get out of their customary isolation. Collaborative design and piloting of curricular alternatives can be very productive, especially when experiences are exchanged and reflected upon in a structured curriculum discourse. Interaction with external facilitators can contribute to careful explorations of the 'zone of proximal development' of teachers and their schools. Cross-fertilization between curriculum, teacher, and school development is a conditio sine qua non for effective and sustainable curriculum improvement. The increasingly popular mission statements of schools to become attractive and inspiring environments for students and teachers can only be realized when such integrated scenarios are practised.

The potential of curriculum design research

Various motives for initiating and conducting curriculum design research can be mentioned. A basic motive stems from the experience that many research approaches (e.g. experiments, surveys, correlational analyses), with their focus on descriptive knowledge, hardly provide prescriptions with useful solutions for a variety of design and development problems in education. Probably the greatest challenge for professional designers is how to cope with the manifold uncertainties in their complex tasks in very dynamic contexts. If they do seek support from research to reduce those uncertainties, several frustrations often arise: answers are too narrow to be meaningful, too superficial to be instrumental, too artificial to be relevant, and, on top of that, they usually come too late to be of any use. Curriculum designers do appreciate more adequate information to create a solid ground for their choices and more timely feedback to improve their products. Moreover, the professional community of developers as a whole would be helped by a growing body of knowledge of theoretically underpinned and empirically tested design principles and methods.

Another reason for curriculum design research stems from the highly ambitious and complex nature of many curriculum reform policies in education worldwide. These reform endeavors usually affect many system components, are often multi-layered, including both large-scale policies and small-scale realization, and are very comprehensive in terms of factors included and people involved. Those radical 'revolutions', if promising at all, cannot be realized on the drawing table. The scope of diverse needs is often very wide, the problems to be addressed are usually ill-specified, the effectiveness of proposed interventions is mostly unknown beforehand, and the eventual success is highly dependent on implementation processes in a broad variety of contexts. Therefore, such curriculum reform efforts would profit from more evolutionary (interactive, cyclic, spiral) approaches, with integrated research activities to feed the process (both forward and backward). Such an approach would provide more opportunities for 'successive approximation' of the ideals and for more strategic learning in general. In conclusion: curriculum design research seems a wise and productive approach for curriculum development.

Features of curriculum design research

Curriculum design research is often initiated for complex, innovative tasks for which only very few validated principles are available to structure and support the design and development activities. Since in those situations the image and impact of the intervention to be developed is often still unclear, the research focuses on realizing limited but promising examples of those interventions. The aim is not to elaborate and implement complete interventions, but to come to (successive) prototypes that increasingly meet the innovative aspirations and requirements. The process is often cyclic or spiral: analysis, design, evaluation and revision activities are iterated until a satisfying balance between ideals and realization has been achieved.

To what extent do these design research activities differ from what is typical for design and development approaches in professional practices? What are the implications of the accountability of researchers to the 'scientific forum'? At the risk of exaggerating the differences, let us outline some of them, based on what is known about routinized standard-patterns in curriculum development practices. Of course, a lot of activities are more or less common for both approaches, so the focus will be on those additional elements that are more prominent in design research than in common design and development practices.

(1) Preliminary investigation

A more intensive and systematic preliminary investigation of curriculum tasks, problems, and context is made, including searching for more accurate and explicit connections of that analysis with state-of-the-art knowledge from literature. Some typical activities include: literature review; consultation of experts; analysis of available promising examples for related purposes; case studies of current practices to specify and better understand needs and problems in intended user contexts.

(2) Theoretical embedding

More systematic efforts are made to apply state-of-the-art knowledge in articulating the theoretical rationale for curriculum design choices. Moreover, explicit feedback to assertions in the design rationale about essential characteristics of the intervention (substantive design principles) is made after empirical testing of its quality. This theoretical articulation can increase the 'transparency' and 'plausibility' of the rationale. Because of their specific focus, these theoretical notions are usually referred to as 'mini'- or 'local' theories, although sometimes connections can also be made to 'middle-range' theories with a somewhat broader scope.

(3) Empirical testing

Clear empirical evidence is delivered about the practicality and effectiveness of the curriculum for the intended target group in real user settings. In view of the wide variation of possible interventions and contexts, a broad range of (direct/indirect; intermediate/ultimate) indicators for 'success' should be considered.

(4) Documentation, analysis and reflection on process and outcomes

Much attention is paid to systematic documentation, analysis and reflection on the entire design, development, evaluation and implementation process and on its outcomes in order to contribute to the expansion and specification of the methodology of curriculum design and development.

More than most other research approaches, design research aims at making both practical and scientific contributions. In the search for innovative 'solutions' for curriculum problems, interaction with practitioners (in various professional roles: teachers, policy makers, developers, and the like) is essential. The ultimate aim is not to test whether theory, when applied to practice, is a good predictor of events. The interrelation between theory and practice is more complex and dynamic: is it possible to create a practical and effective curriculum for an existing problem or intended change in the real world? The innovative challenge is usually quite substantial, otherwise the research would not be initiated at all. Interaction with practitioners is needed to gradually clarify both the problem at stake and the characteristics of its potential solution. An iterative process of 'successive approximation' or 'evolutionary prototyping' of the 'ideal' intervention is desirable. Direct application of theory is not sufficient to solve those complicated problems. One might state

that a more ‘constructivist’ development approach is preferable: researchers and practitioners cooperatively construct workable interventions and articulate principles that underpin the effects of those interventions.
Another reason for cooperation is that without involvement of practitioners it is impossible to gain clear insight in potential curriculum implementation problems and to generate measures to reduce those problems. New interventions, however imaginative their design, require continuous anticipation at implementation issues. Not only for ‘social’ reasons (to build commitment and ownership of users) but also for ‘technical’ benefits: to improve their fitness for survival in real life contexts. Therefore, rigorous testing of practicality is a conditio sine qua non in design research.

Emphasis on formative evaluation

As has become clear in the previous sections, formative evaluation holds a prominent place in curriculum design research. The main reason for this central role is that formative evaluation provides the information that feeds the cyclic learning process of curriculum developers during the subsequent loops of a design and development trajectory. It is most useful when fully integrated in a cycle of analysis, design, evaluation, revision, et cetera, and when contributing to improvement of the curriculum.
The basic contribution of formative evaluation is to quality improvement of the curriculum under development. Quality, however, is an abstract concept that requires specification. During development processes, the emphasis in criteria for quality usually shifts from relevance, to consistency, to practicality, to effectiveness[2]. Relevance refers to the extent that the intended curriculum is perceived to be a relevant improvement to practice, as seen from the varied perspectives of policy makers, practitioners and researchers. Consistency refers to the extent that the design of the curriculum is based on state-of-the-art knowledge and that the various components of the intervention are consistently linked to each other (cf. the curricular spider web). Practicality refers to the extent that users (and other experts) consider the intervention as clear, usable and cost-effective in ‘normal’ conditions. Effectiveness refers to the extent that the experiences and outcomes with the intervention are consistent with the intended aims.

The methods and techniques for evaluation will usually be attuned to that shift in criteria. For example, validity can adequately be evaluated through expert appraisal, practicality via micro-evaluations and try-outs, and effectiveness in field tests. In later stages of formative evaluation, methods of data collection will usually be less intensive but with an increasing number of respondents (e.g. achievement test for many students compared to in-depth interview with a few experts).

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2) See for these criteria also chapters 1 and 5.

Formative evaluation within development research should not only concentrate on locating shortcomings of the intervention in its current (draft) version, but especially generate suggestions on how to improve those weak points. Richness of information, notably salience and meaningfulness of suggestions in how to make an intervention stronger, is therefore more productive than standardization of methods to collect and analyze data. Also, efficiency of procedures is crucial. The lower the costs in time and energy for data collection, processing, analysis and communication will be, the bigger the chances on actual use and impact on the development process. For example, samples of respondents and situations for data collection will usually be relatively small and purposive compared to sampling procedures for other research purposes. The added value of getting 'productive' information from more sources tends to decrease, because the opportunities for 'rich' data collection methods (such as interviews and observations) are limited with big numbers. To avoid an overdose of uncertainty in data interpretation, often triangulation (of methods, instruments, sources, and sites) is applied. These arguments especially hold true for early stages of formative evaluation, when the intervention is still poorly crystallized.

Generalization of curriculum design research findings

The practically most relevant outcome of curriculum design research is its contribution towards optimization of the curricular product and its actual use, leading to better instructional processes and learning results. However, a major contribution to knowledge to be gained from design research is in the form of (both substantive and methodological) 'design principles' to support developers in their task. Those principles are usually heuristic statements of a format such as: "If you want to design curriculum X [for the purpose/function Y in context Z], then you are best advised to give that curriculum the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of theoretical and empirical arguments P, Q, and R." Obviously those principles cannot guarantee success, but they are intended to select and apply the most appropriate (substantive and procedural) knowledge for specific design and development tasks.

It is not uncommon in design research that such knowledge, especially the substantive knowledge about essential curriculum characteristics, can partly be extracted from a resulting prototype itself. That is one of the reasons that make it so profitable to search for and carefully analyze already available curricula to generate ideas for new design tasks. However, the value of that knowledge will strongly increase when justified by theoretical arguments, well-articulated in providing directions, and convincingly backed-up with empirical evidence about the impact of those principles. Moreover, those heuristic principles will be additionally powerful if they have been validated in successful design of more interventions in more contexts. Chances for such knowledge growth will increase

when design research is conducted in the framework of research programs, because projects can then build upon one another.
Since data collection in design research is often limited to small (and purposive) samples, efforts to generalize findings cannot be based on statistical techniques, focusing on generalizations from sample to population. Instead one has to invest in 'analytical' forms of generalization (cf. Yin, 2003): readers/users need to be supported to make their own attempts to explore the potential transfer of the research findings to theoretical propositions in relation to their own context. Reports on design research can facilitate that task of analogy reasoning by a clear theoretical articulation of the design principles applied and by a careful description of both the evaluation procedures as well as the implementation context. Especially a 'thick' description of the process-in-context may increase the 'ecological' validity of the findings, so that others can estimate in what respects and to what extent transfer from the reported situation to their own is possible. Another option that may stimulate exploration of possibilities for (virtual) generalization is to organize interactive meetings with experts from related contexts to discuss the plausibility of the research findings and recommendations for related tasks and contexts.
Last but not least, design research may offer drafts of various relevant curriculum versions (with proven consistency and practicality) that can be compared in more quantitative, large-scale studies.

References

Cuban, L. (1992). Curriculum stability and change. In P. Jackson (Ed.), *Handbook of research on curriculum* (pp. 216-247). New York: Macmillan.

Goodlad, J. (1994). Curriculum as a field of study. In T. Husén, & T. Postlethwaite (Eds.), *The international encyclopedia of education* (pp. 1262-1276). Oxford: Pergamon Press.

Fullan, M. (2001). *The new meaning of educational change.* New York: Teachers College Press.

Marsh, C., & Willis, P. (2003). *Curriculum: Alternative approaches, ongoing issues* (third edition). Upper Saddle River, NJ: Merrill/PrenticeHall.

Pinar, W., Reynolds, W., Slattery, P., & Taubman, P. (1995). *Understanding curriculum. An introduction to the study of historical and contemporary curriculum discourses.* New York: Peter Lang.

Taba, H. (1962). *Curriculum development: Theory and practice.* New York: Harcourt, Brace & World.

van den Akker, J. (1999). Principles and methods of development research. In J. van den Akker et al. (Eds.), *Design approaches and tools in education and training* (pp. 1-14). Dordrecht: Kluwer Academic Publishers.

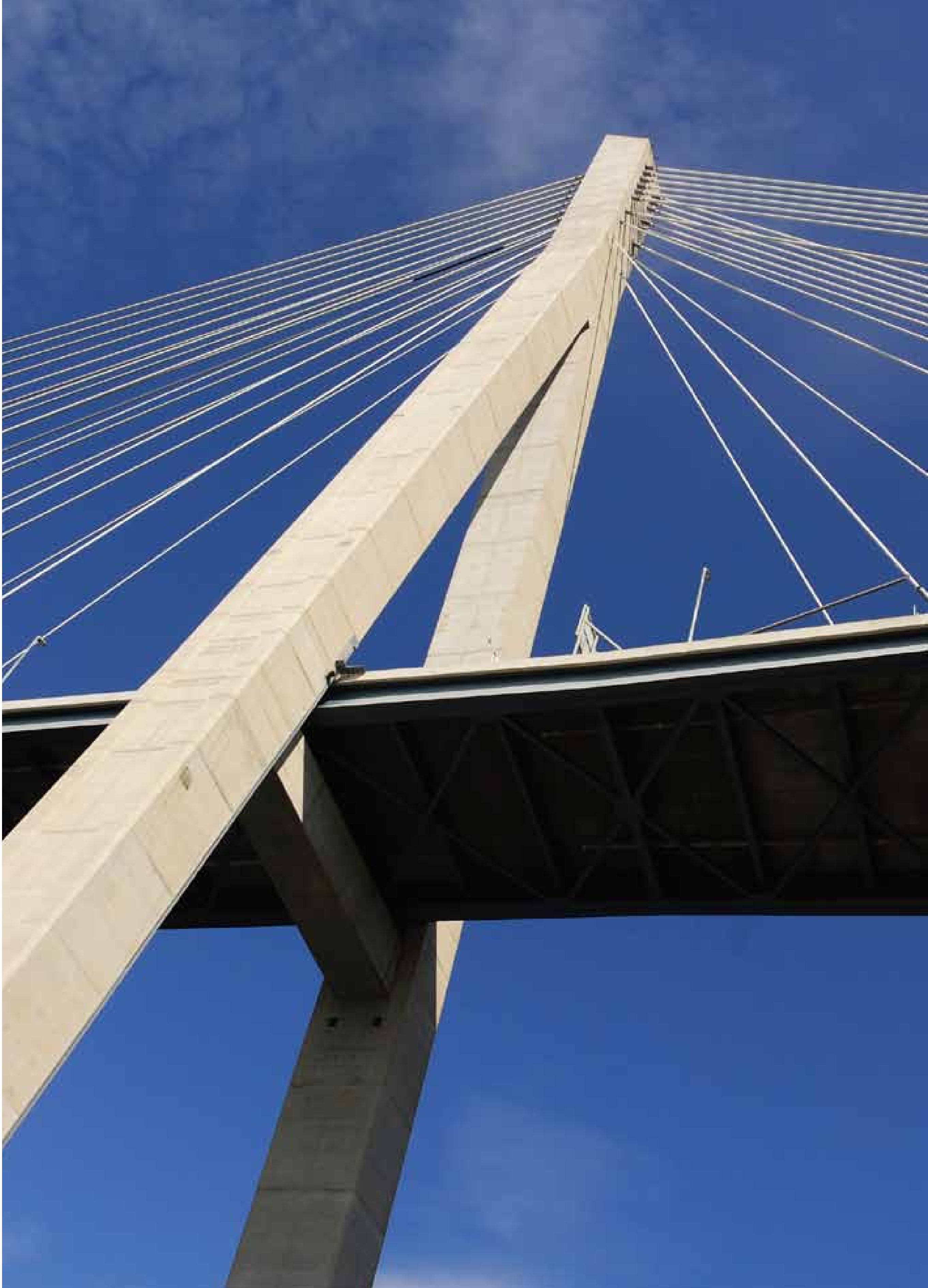
van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1-10). Dordrecht: Kluwer Academic Publishers.

van den Akker, J., Branch, R., Gustafson, K., Nieveen, N. & Plomp, T. (Eds.) (1999). *Design approaches and tools in education and training.* Dordrecht: Kluwer Academic Publishers.

van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (Eds.) (2006). *Educational design research.* London: Routledge.

Walker, D. (2003). *Fundamentals of curriculum: Passion and professionalism.* Mahwah, NJ: Lawrence Erlbaum Associates.

Yin, R. K. (2003). *Case Study Research: Design and Methods.* London: Sage.

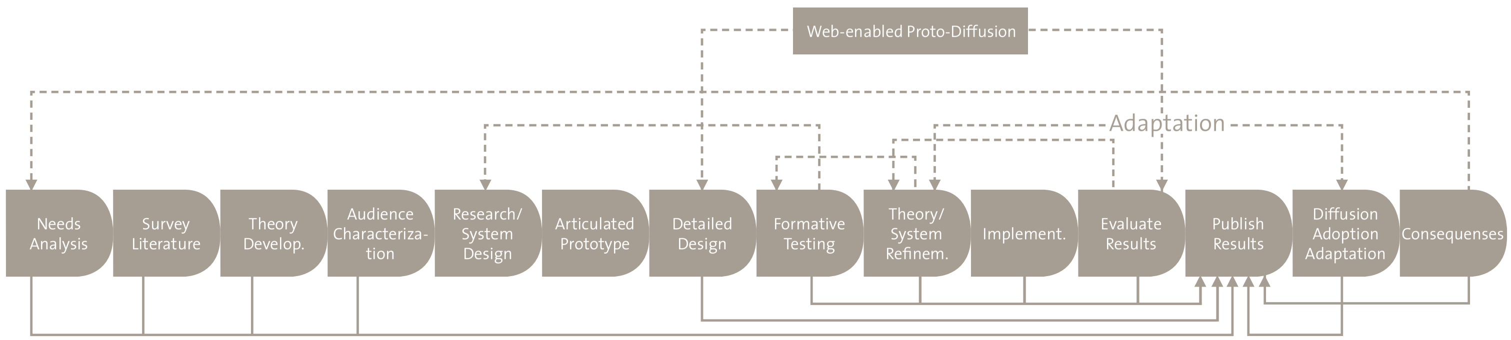


3. The Integrative Learning Design Framework: An Illustrated Example from the Domain of Instructional Technology

Brenda Bannan

Articulating a clear definition and process of design research is a current and prominent topic among educational researchers (Kelly, Lesh & Baek, 2008; van den Akker, Gravemeijer, McKenny and Nieveen, 2006). Design research studies involve complex interactions and feedback cycles that can significantly blur the roles of researchers, teachers, curriculum developers, instructional designers and assessment experts (Kelly, Lesh, Baek & Bannan-Ritland 2008). As educational researchers struggle to clarify this research method, they continue to raise significant questions such as how is design research different from the process of design? What are appropriate methods and processes that can be used in design research? How do we systematically create, test and disseminate design or teaching interventions that will have maximum impact on practice capitalizing on design research? How do we generate both theoretical and practical knowledge related to complex educational settings?

Kelly (2006) and others (Fishman, Marx, Blumenfeld, Krajcik & Soloway, 2004; Zaritsky, Kelly, Flowers, Rogers & O'Neill, 2003; Rogers 2003; Collins, 1999; Design-based Research Collective, 2003) advocate that these emerging methods call for the articulation of new processes and criteria including factors such as the usefulness and usability of knowledge, its shareability, and marketability, how well it disseminates and the extent to which it positively impacts practice. Sabelli (personal communication, May 16, 2002) cites a need for organizational structure and protocol for the diffusion of research into practice and states that educational research situations are extremely complex systems that can benefit from integrated system research strategies. There is a need for comprehensive models to guide design research addressing the process of designing, developing and assessing the impact of an educational innovation. In this chapter, I present an integration of existing design and research processes offering a guiding framework that goes beyond the individual domains of social science, behavioral science and communication theory and attempts to integrate the systematic processes of the related fields of instructional design, software engineering, product design, hence the name Integrative Learning Design Framework (ILDF). Building on the integration of processes from multiple fields such as instructional design, object oriented software development, product development and diffusion of innovations and educational research, the ILDF present a "meta-methodological" view that attempts to integrate the best of design, research and diffusion of educational innovations. This framework consisting of four phases (see Figure 1) challenges researchers to provide improved articulation of design research processes by phase and to consider the entire scope of research from initial conceptualization to diffusion and adoption.



ILD	Informed Exploration	Enactment	Evaluation: Local Impact	Evaluation: Broader Impact
Guiding Questions for Research	Questions: - What are identified gaps/problems in theory, practice and/or the marketplace? - What information can be gleaned from existing data or research? - How can we characterize the problem or leaner need? - What are the systemic social, cultural, and organizational influences or constraints on design? - What are characteristics of the audience?	Questions: - What are the learning targets for innovation? - What design principles or strategies may be applicable? - How to identify and operationalize cognitive and performance processes in design? - To what extent does the design embody the theoretical model?	Questions: - Is the enacted design usable, valid and relevant? - Is the design instance accessible and efficient in delivering instruction or supporting learning? - What is the local impact or effectiveness of the design instance? - How effective is the design solution in achieving learning targets at its highest fideliy in full context?	Questions: -What factors influence diffusion, adoption and adaption of innovation? - What are the pragmatic demands of the learning environment that influences adoption of design? - What policies and cultures shape participants use of innovation?
Applicable Research Methods	Methods: - Benchmarking - Performance/needs analysis - Interviews - Survey of Experts - Focus Groups - Observation/Role Modeling - Case Studies	Methods: - Task Analysis - Contextual Analysis - Designer Logs - Expert Review - Audience Review	Methods: - Usability Testing - Expert Review - Observation or Video records - Interviews - Formative Evaluation - Pre-post Comparative Studies - Quasi-experimental studies	Methods: - Analysis of computer log files - Multi-site Interviews, Surveys and Observations - Data mining - Correlational studies - Quasi-experimental studies

Figure 1: Questions and Methods for Design Research by ILDF Phase

The four phases of Informed Exploration, Enactment, Local Evaluation and Broad Evaluation presented in the ILDF encompass a process model for conducting design research based on several years of attempts to incorporate progressively more rigorous, research-based cycles within a technology-based instructional design effort. This type of effort is different than traditional instructional design as the iterative cycles are essentially micro-cycles of research (more comprehensive qualitative and quantitative research efforts than formative evaluation cycles) conducted to learn more than how to improve the technology system, although the studies may also result in that outcome. The reference to learning within the ILDF is to place emphasis on the learning that can result in the context and activity of design. For example, as researchers or instructional designers we may generate information about the teaching and learning process, participants, context, and culture that is often not attended to, discarded and captured in a rigorous manner for others to learn from and capitalize on. Whether our design activity involves classroom-based interventions, technology or some combination of both, the interconnected design research cycles can generate knowledge about design principles but also provide rich information on aspects of learning, cognition, expert and novice perspectives, as well as stakeholder positions to direct design and design decision-making. The core issue at hand is that the rich, complex, design process may offer multiple opportunities to generate research-based knowledge however, much of it is lost and not documented in the creative design process. Our challenge, as design researchers, is to try to systematically gather, analyze, report and codify this information in a rigorous manner that strives toward some type of logical, argumentative grammar worthy of stringent research processes (Kelly, 2006).

Connected cycles of research cycles and design processes result in improved decision-making based on data-driven results for design, development and research purposes. Though clearly interventionist and primarily formative in nature, the ILDF process stands apart from traditional instructional design and research efforts. Throughout the multiple phases and cycles of integrated research and design processes valuable knowledge in the context of use is generated . We need to mine what is learned about important factors related to learning, context, culture, and technology within the design process (not separate from it in a controlled setting as evidenced in traditional research). If design researchers can articulate an integrative research and design process, it may have the potential to significantly improve our understanding of teaching, learning and training in-situ. The multiple macro and micro-cycles of data collection, analysis and most importantly, results-driven design decision-making is what sets design research apart from traditional formative evaluation in instructional design which is often conducted in a very limited manner or a single cycle of data-gathering and analysis.

Tessmer (1993) refers to formative evaluation as a "judgment of the strengths and weakenesses of instruction in its developing stages, for purposes of revising the instruction to improve its effectiveness and appeal (p. 11)". Although multiple methods may be used including expert review, one-to-one evaluation, small group and field testing, formative evaluation cycles in traditional instructional systems design may not always employ research methods that are specific to particular phases of an integrative and connected design research cycle. Formative evaluation, despite its most rigorous and comprehensive application does not progressively generate knowledge about cognition, context and culture of use but provides a limited focus on a particular technology system of instruction and judges its effectiveness, appeal and efficiency. In contrast, design research cycles are based on a thorough, systematic process integrated multiple design and research processes to progressively improve understanding about learners, learning, context, or culture as well as iteratively improve an intervention. Therefore, formative evaluation methods are subsumed as one selected method in what could be described as a "meta-methodological" or involving multiple research methods across the design research process. What is critical in design research is the theoretical yield of the effort to be viewed as important as the improvement of the intervention (see Plomp chapter 1).

Design research cycles are dynamic and integrate multiple exploratory, constructive and/or empirical research methods as well as multiple design/development techniques (see Figure 1). Exploratory research methods structure and identify new problems such as feasibility testing, benchmarking and qualitative research approaches. Constructive research develops solutions to problems and may include testing of a construct or theory against a predefined criteria and may, for example, include formative evaluation testing of an instructional technology system. In contrast, empirical research tests the feasibility of a solution using empirical or direct or indirect observation or evidence in the tradition of the scientific method. Design research may employ all three forms of research methods as well as incorporate formative evaluation methods at different phases in the process. However, traditional, formative evaluation perspectives while offering valuable iterative processes, do not in isolation, address the complexity inherent in educational practice. Most educational research projects advocate only one cycle of qualitative or quantitative empirical testing at a fixed point in time for a given instructional intervention for the sole purpose of generating knowledge. In contrast, design research attempts to progressively and dynamically generate (exploratory research), improve (constructive research) and learn about (empirical research) a particular phenomenon from interconnected research and design cycles.

In response to this challenge, the ILDF model attempts to provide a comprehensive yet dynamic and flexible guiding framework that positions multiple, micro and macro design research cycles as primarily socially-constructed, contextualized process of producing the most educationally effective product that has the best chance to be used in the classroom while also generating knowledge about teaching and learning within the activity of design. The model or framework attempts to move past isolated, individual efforts of educational research by clearly articulating a logically-ordered structural frame that considers the full spectrum of research methodology in advancing toward systemic impact in education and may be applied in a variety of contexts. Collins (1990; 1993) advocates for a similar overt, systematic methodology for conducting design experiments and states:

> **"When designing a learning environment, whether computer based or not, there are a multitude of design decisions that must be made. Many of these design decisions are made unconsciously without any articulated view of the issues being addressed or the tradeoffs involved. It would be better if these design decisions were consciously considered, rather than unconsciously made (1993, p.1)."**

The ILDF process presents one step toward a systematic framework for the articulation and documentation of common phases and complementary stages based on multiple design and research processes promoting more conscious design research (Collins, 1990; 1999). Although there are thousands of decisions made in a design research context, the major conjectures, learning targets, task analysis, design principles and evaluation or research decision-making resulting from exploratory, constructive and/or empirical research cycles may be uncovered by examining a rich case study as presented here entitled the LiteracyAccess Online (LAO) project. The ILDF is presented here as a starting point for researchers to consider as with the goal of eliciting questions, suggestions, limitations and criteria that may need to be considered as researchers struggle with the implications of this emerging form of educational research. In this chapter, I briefly describe the progression of the LAO design-based research study that encompassed four years of effort and illustrates the application of the ILDF. The LAO case study example is described according to broad phases including 1) the informed exploration phase; 2) the enactment phase; 3) the local impact phase; and 4) the broad impact phase as well as the multiple potential applied and empirical research processes that align with each phase (see Figure 1). It is hoped that the LAO example will provide enough detail to potentially improve understanding of conducting cycles of design research related to a technology-based educational intervention.

LiteracyAccessOnline - An integrative learning design study

The LiteracyAccess Online (LAO) project[1] provides an example of an integrative learning design study based on the ILDF specifically illustrating the intersection and systematic expression of multiple design and research methods. LiteracyAccess Online is an effort to utilize Web-based technology to provide support for teachers, tutors, and parents (literacy facilitators) in addressing literacy goals for all children with a particular focus on those with disabilities. After four years of design research and development, LAO (http://literacyaccessonline.com) now provides a technology-based learning environment that promotes the use of specific literacy strategies for the improvement of tutoring and reading performance as the child and literacy facilitator collaboratively engage in the process of reading online.

The Informed Exploration Phase

The exploratory research objectives of the LAO integrative learning design study were two-fold;

1) to investigate the nature and effectiveness of a consistent technology-based, collaborative literacy environment as well as;
2) to generate knowledge about how literacy facilitators and children understand and employ reading support strategies.

These objectives were originally conceived as research/evaluation questions and evolved from an extended, progressive investigation into the provision of literacy support for facilitators and children. This "meta-methodological" design research process consisting of multiple research methods (e.g. survey, focus groups, interviews, expert reviews, etc) resulted in clearly articulated learning targets, task analyses of learning objectives, theoretical model embedded in a technology system design and congruent research/evaluation questions that drove more rigorous qualitative testing of the intervention whose results contributed to theory of literacy support for children with disabilities further elaborated in sections below.

To begin exploratory research cycles, initial explorations into target audience and stakeholder perceptions, related products and literature and documentation of the complex nature of supporting literacy revealed many plausible paths for design research. The interdisciplinary research team involved in the LAO project were charged with determining the research direction and consisted of educational researchers, teachers, graduate students, content experts in literacy, special education and assistive technology as well as parents involved in an advocacy group for children with disabilities. The broad design research

[1] The LiteracyAccess Online (LAO) project is supported by the Office of Special Education Programs in the Department of Education Steppingstones of Technology Innovation for Students with Disabilities Grant CFDA84.327A

focus evolved from the team's perceived lack of support for children who were struggling with the literacy process, based on direct observations of this problem in both classroom and home environments which then manifested itself into several individual but connected research studies. For example, we conducted multiple interviews with parents with children with disabilities who were struggling with the reading process. We also invited several parents to participate on our design research team. The teams' analysis of the interview data as well as the design research team discussions revealed our initial approach. We had initially decided to design a tutorial-based intervention only for the child's benefit, however, a comment in a team meeting dramatically changed our design direction. In line with Collins' notion of conscious considerations of design as demonstrating core underlying design decision-making, one parent member/stakeholder on the team stated that she primarily read in conjunction with (not to) her son and wanted to do so online but with additional support of higher level reading strategies. Based on that input and follow-up micro-cycles of interview data collection and analysis to confirmation the viability of this design approach with parents, we conducted a series of interviews and surveys to determine the feasibility of this design direction. The results of our investigation and discussions evolved into an online collaborative performance support system to support both literacy facilitators and their children in the literacy process as the determined design direction. This was a design decision based on data analyzed from multiple interviews and survey procedures. Aligned with Confrey and Lachance's (2000) notion of drawing key inferences from dissatisfaction with current educational practices and direct experiences with children, initial theoretical conjectures were developed based on the analyzed data that advocated for reading, writing and assistive technology support for children with or without disabilities to increase their engagement and performance in literacy.

While these initial theoretical conjectures provided a central premise and broad direction for design research, more information was needed to refine these conjectures resulting in a comprehensive needs analysis and literature review that provided a firm and complementary theoretical foundation for the intended design. Extensive exploration into appropriate literacy strategies, tutorial programs and processes, surveys of experts, teachers and parents as well as qualitative observation of children and facilitators engaged in a literacy experience all informed this phase of the research. This provided not only well-defined design directions but also added to the research literature regarding children with disabilities and their parents understanding of assistive technology and literacy learning (see Jeffs, Behrman & Bannan-Ritland, 2006). Many potential design research directions were considered based on the initial conjectures, however, data drawn from conducted interviews, direct experience with potential research participants and literature review converged and pointed the team in a particular direction.

A prominent theme that emerged across initial interviews, surveys and observations with experts, parents, teachers and children revealed that literacy facilitators had a crucial role in providing support for children struggling to gain literacy skills and the question remained how to best support this role. These findings and related literature provided insight for informed theory and improved conjectures based on the aforementioned qualitative interviews and literature reviews. Results from data collection and literature review methods in the informed exploration phase indicated that:

1) children can, but often do not use effective metacognitive reading strategies;
2) explicitly teaching these strategies can greatly enhance children's comprehension of text;
3) teachers (as well as other literacy facilitators) need to be trained in how to provide cognitive structure for their students so that children can learn to guide their own generative processes in reading; and
4) one-to-one tutoring is one of the most effective forms of instruction for improving reading achievement but increased success often depends upon the skill of the tutor or facilitator and the establishment of consistent roles and expectations (Wittrock, 1998; Wasik, 1998).

This exploration into the literature and perspectives of those involved in these issues greatly refined our initial theoretical conjectures and resulted in a dramatic change of our intended design direction for this research from a didactic, tutorial, child-focused intervention to a collaborative, story-based reading experience providing embedded metacognitive strategy support for both the literacy facilitator and the child's use. The rationale for this research direction was documented in a comprehensive needs analysis that detailed the data collection, conclusions and related literature review.

The next stage of our design research involved the analysis and description of the range of learners and facilitators that would potentially use the LAO system. Direct experience with 4^{th}-8^{th} grade children with or without disabilities, teachers, tutors, and parents provided data that characterized our audience. These descriptions were depicted as role models (Constantine & Lockwood, 1999) or personas (Cooper, 1999) that comprised abstract composite profiles of audience characteristics gleaned from actual interviews and observations and provided a focal point for design. Role models or personas are similar to Graue and Walsh's (1998) qualitative vignettes that strive to capture the substance of a setting, person or event to communicate a central theme of qualitative data, based on multiple direct observations and are employed here as also a focal point for design. Exploring the nature of the identified educational problem, related products and literature as well as creating and refining theoretical conjectures and descriptions of the audience provided an informed perspective for grounded design of a learning environment based on articulated theory. These activities resulted in specific research artifacts including a needs analysis that contained an extensive literature review, an articulated and congruent design and research direction and detailed audience analysis based on qualitative and quantitative data. These documents were housed on a project Web site that provided a communication mechanism between team members as well as an archive of shareable design research processes, products and evidentiary data.

The Enactment Phase

The embodiment of the results of our informed exploration and theories about providing literacy support for children and literacy facilitators in a usable learning environment were collaboratively constructed across several stages and constructive research cycles that develop solutions to problems culminating in a Web-based prototype. The initial design of the LAO learning environment resulted directly from the design implications articulated in the previous phase of exploratory research, analyses and review. These implications were translated into an articulated prototype initially developed by building an abstract, paper-based model of the system for researcher and teacher input according to procedures adapted from usage-centered design processes previously mentioned as role models (Constantine & Lockwood, 1999). Role models are a technique to characterize primary and secondary target audiences for the purposes of design. For example, we created role models and personas for children with learning disabilities (such as attention deficit disorder) based on our direct experience with a child who was struggling in the reading process and his mother who did not have any knowledge of advanced reading support strategies. These techniques are based on real-world experiences with representatives of the target audiences your intervention or system is being designed for but evolve into a archetypal composite of the attributes of many individuals. Therefore, role models and persona's become a qualitative profile to continually target design efforts to maintain the audience(s) or user(s) perspectives.

Abstract or low-fidelity modeling/prototyping of the instantiated or enacted design provided opportunities for input and co-construction of LAO with several audience members prior to the more time-intensive computer-based production of the learning environment. We utilized Constantine and Lockwood's (see foruse.com) procedures of usage-centered design that encompassed low-fidelity representation and organization of all the features of the database-driven Website. For LAO, we deliberately ultimately designed a Web database system that would permit performance support for the parent-child dyad in providing meta-cognitive prompts for both participants based on research-based reading strategies throughout a collaborative and generative process of engaging with text.

In the context of a constructive research approach that attempts to validate a particular construct (e.g. theory, model, software or framework) against identified criteria or benchmarks, the team conducted several iterative cycles of data-gathering and analysis of expert reviews and target audience reviews. These progressive, micro-cycles of data collection and analysis resulted in data-driven cyclical revisions of the articulated prototype which were reflected in detailed design documentation including the production of flowcharts, technical specifications and storyboards. The design research process of employing micro-cycles of constructive research data gathering and analysis elicited feedback at each cycle and design revisions agreed upon by the team which resulted in the initial creation and then progressive improvement of a Web-based prototype validated by data collected in a constructive research approach. As a team, we constructed specific criteria related to usability of system and observations and video analysis of actual use of the system by literacy facilitators and children. The specific methods of data collection employed at this stage included designer logs posted on the project Web site, expert panel reviews of the design and documented reviews of the design by content experts, audience members and the research team.

The Local Impact Phase

Once a physical Web-based prototype was in place, the incorporation of formative evaluation and qualitative methods in an empirical manner could commence and began to characterize the rich, highly iterative nature of the local impact phase as it progressively informed, revised and refined our theoretical constructs as well as the Web-based instructional design approach and redesign efforts. The complex interactions between facilitators and children that can occur in multiple settings formed the series of micro-cycles in LAO examining these specific constructs that grounded related research questions: 1) parent-child dyads in an informal setting with extensive involvement by researchers; 2) parent-child dyads in a structured workshop experience supported by researchers and; 3) pre-service-teacher dyads in a field trial progressing toward more closely modeling authentic conditions experienced with the prototype. When a fully functioning prototype was not yet available, studies attempted to closely mimic the tasks that would be embedded in LAO. The data gathering across these three studies incorporated observations, interviews, child and parent journal entries, videotaped use of system and pre- and post-online surveys (see Jeffs, Behrmann & Bannan-Ritland, 2006). This multi-tiered, multi-method evaluation scheme generated useful knowledge and subsequent results from each stage of inquiry were then cycled into changes of our theoretical conjectures, research design as well as system design. This process revealed insights into the core design principles (van den Akker, et al., 2006) that may support the collaborative learning and implementation of metacognitive processes by literacy facilitators and children in a technology-based environment.

Our core design principles that evolved and were refined included the following that when engaged in a collaborative literacy process that provides high level reading strategy metacognitive support in a Web-based context:

1) parent literacy facilitators could develop greater awareness and skill in implementing reading activities and identify supports for their child in a structured setting;
2) children showed improvement in literacy skills using technology-based support when participating in a guided workshop environment; and
3) pre-service teachers felt that the strategies and activities embedded in the LAO environment facilitated children's comprehension, motivation and interest when working with them in this environment (see Jeffs, et. al. 2006).

More rigorous evaluations are planned for the future to systematically increasing number of participants and varying contexts for the use of LAO in school, home and tutoring environments. These studies involve detailed tracking of computer-based activities of the dyads in school and home settings, assessment of facilitator and child use of metacognitive strategies prior to using LAO and pre- and post comprehension measures after several weeks of using the system.

In addition, a series of expert reviews, usability testing, one-to-to-one, small group, and field testing were implemented in progressively more authentic settings. The more intensive studies focused primarily on qualitative studies that characterized the target audience interaction with the enacted theoretical model in relation to the learning targets. Specifically, the team was interested in how facilitators and learners perceived and interacted with Web-based support in the collaborative literacy process (which included both reading and writing tasks). A pilot study was initially conducted that simulated some tasks within LAO and provided feedback on the emerging site with five dyads of mostly parent facilitators and one sibling facilitator. Methods included collecting data through semi-structured interviews and observations of parent-child interaction with the prototype and complementary assistive technologies (e.g. text-to-speech, etc.) that promoted in reading and writing activities.

The preliminary study revealed that the children were motivated to complete reading and writing activities on the Web and that facilitators developed awareness for implementing reading activities in a collaborative process but desired additional support for children's disabilities. While the Web-based activities and supports for the reading process were useful for providing more authentic and self-initiated reading and writing activities, the research also revealed that interaction between parent and child dyads during these activities often created tensions that were not present when children were working with non-family members. Revisions to the theoretical model and enacted design of LAO based on this cycle of evaluation included among others, behavioral prompts directed toward the parent-child dyad to potentially release tension (such as prompts to take a break, positive reinforcement techniques, etc.) when engaged in collaborative reading and writing tasks and additional reading strategy supports and activities.

To further investigate the enacted theoretical model, a follow-up small group qualitative study was conducted with eight parent/child dyads that represented a variety of skill levels and disabilities (Jeffs, 2000). The specific goals of this cycle of research was to identify the characteristics of parent/child dyads working together specifically in literacy skill development, depict the interactions of the dyad and investigate the impact of various forms of technology (Internet, EPSS and any assistive technology) on attitudes of the participants. Participants included parents and children with various disabilities in grades 4th through 6th who were reading at least two grades below grade level and had a tendency to avoid reading and writing tasks prior to participation in the study. The study revealed that parents recognized the importance of immediate feedback and assistive technology features in the provided tools. Other results revealed that with the support of their parents, children can select appropriate technologies and with integrated use of the Internet and assistive technologies, children's writing samples improved in both quantity and quality. Suggested revisions for the LAO prototype based on these results included built-in assistive technology features (instead of merely references to outside resources) such as text-to-speech capabilities and reading selections reflecting varying abilities and areas of interest – features that were subsequently incorporated into the LAO design.

In each of these cycles of problem-state, data collection, analysis and subsequent design move or formative evaluation process, the theoretical model enacted within the LAO prototype expanded to incorporate new and revised elements based on targeted data collection and research results. At this point, traditional research and design processes somewhat diverge in that the analyzed results are not an end in and of themselves, but are used for data-driven decision making or problem solving to build upon or revise theoretical assumptions and improve design. Often, based on testing results, we would need to throw out previous prototype features and totally redesign, revise or add new features. The team's informed design judgment and collaborative social negotiation was key to this decision-making.

The local impact phase is a time-intensive phase with multiple cycles that strives to yield a usable and internally valid intervention. Testing the intervention in progressively more realistic settings provides valuable information to inform theoretical assumptions related to the design but also to begin to isolate variables that might be further empirically tested. In the LAO research conducted to date, the integration of reading strategy scaffolds and assistive technology supports in the collaborative literacy process between facilitators and children with a range of disabilities was identified as one factor, of many, that seem to hold promise for improving literacy skills. Conducting additional research to further investigate the collaborative process promoted by the technological environment as well as isolating the effects of the multiple reading supports and assistive technologies afforded by the prototype remains an important objective in this research.

Although the funding cycle for LAO has ceased, in order to progress from local effects to more externally generalizable effects, additional cycles of testing are needed to isolate and test particular variables using multiple sites, diverse participants and settings progressively limiting the researcher-participant interaction. Based on available funding, field tests or trials are planned for LAO to collect significant amounts of quantitative and qualitative data from several sites and over 50 participant dyads using selected measurements, online surveys and interviews including parents and children in home school environments, pre-service teachers and in-service teachers that could represent other literacy facilitators in several geographical locations interacting with children with a range of disabilities. This data would provide additional evidence for the effectiveness of enacted theoretical assumptions for the collaborative reading and literacy process as well as provide evidence for the effectiveness of the prototype at its highest fidelity in full context of the intended use.

The Broad Evaluation Phase

The last phase of this design-based research effort involves disseminating LAO into the broad educational system. Although the LAO research has not yet fully progressed through this stage, initial explorations in this area have yielded some unique insights into the dissemination process. However, the reader should note that the dissemination process can encompass an entire research effort in itself. For example, Fishman (2006) has applied a design research framework related to the sustainability of technology-based curriculum interventions within an entire school district or system.

LAO, as a Web-based learning environment, affords the opportunity to publish current working prototypes online for open use and input that has resulted in an early and unique diffusion and adoption process begun prior to the completion of a fully functioning system. While still in development, we have tracked over 100 potential adopters that have discovered and explored the LAO site. The profiling and data-base capabilities of the site permit tracking and analysis of this information that has provided detailed information on potential adopters of the system providing significant insight and impact on sources for our later diffusion efforts. We plan to incorporate more sophisticated computer-based data collection and analysis techniques such as datamining (Tsantis & Castellani, 2001) that may yield even more insights into early adopters' behaviors, profiles and use of this new tool. We have just begun to publish our results of the design based research conducted related to LAO in traditional academic journals and non-traditional Web publishing that provide avenues for additional forms of review and evaluation. The results of our initial studies have prompted new research directions such as exploring the interaction of an online community for parents of children with disabilities incorporated in the LAO environment. Given the iterative nature of this type of research, it is highly likely that determining the consequences of the LAO design research effort will yield new theoretical and applied questions that will prompt the entire process once again.

Theoretical yield of literacy access online design research study

Given the design research process based on the Integrative Design Learning Framework described above, what did we learn? The characteristics of an intervention or as van den Akker, et. al. (2006) describe the "design principles" are an important yield of design research. In the LAO project, these design principles included providing metacognitive reading strategy support while a parent, teacher or tutor is engaged in the collaborative reading process with the child delivered through a comprehensive Web-based performance support system.

Design research is often employed to begin to generate theory (Design-based Research Collective, 2003). With LAO, there were no literature sources, theoretical principles or research studies directly applicable to a Web-supported collaborative reading process so the team integrated insights from tutoring, reading strategies and real-time performance support. Zaritsky et. al. (2003) speak to going "...beyond simple development of an intervention and beyond standard cognitive analyses allowing theory and modeling that accounts for the content, the cognition and the enactment by real people in real and rich contexts with real limits on resources (p. 11). The LAO design research team went beyond traditional development with intensive cycles of interviews, surveys, observational studies as well as deep investigation of the one-on-one tutoring and reading strategies literature to build a new theoretical model of real-time metacognitive reading strategy and assistive technology support for both the literacy facilitator and the child with disabilities. Much of these insights were an integration of data analyses, direct experience with target audience members and a grounded literature in reading processes, tutoring and collaborative performance support.

The design research process was conducted systematically to:

1) uncover the initial conjectures about how learning might occur in this type of setting;
2) stated learning targets, task analyses (in this case based on Activity Theory);
3) the designed intervention which embodies the core design principles (metacognitive reading strategy support in a collaborative performance support context);

4) local impact or evaluation questions that drove the more intensive research cycles (see Figure 2).

This progression demonstrates an alignment or congruency from initial conjectures through local impact or evaluation questions that evolved during the design research study. The specific theoretical insights that were tested and revealed based on this process are included in Figure 2. The multiple phases of the IDLF process uncovered many informal and formal theoretical insights based on macro and micro data collection and analysis cycles conducted within the process of design that can be typically overlooked in the traditional instructional design process. For example, extending beyond a traditional learner analyses, we conducted multiple cycles of surveys, interviews, and observations of target audience member interaction that revealed theoretical insights that go beyond just the design of the intervention. Our studies revealed that parents have little formal knowledge and use of good reading strategies when engaged with their child in the reading process. This insight parlayed into the design principles of LAO but also stand apart from it as a finding that may contribute to the literature in the reading field. By formalizing and extending the methods of traditional instructional design to promote rich cycles of data collection that then can inform our knowledge of particular audiences, learning contexts and processes – separate but connected to the design of a particular intervention, we can begin to progress toward generating knowledge and useful theoretical insights that are typically overlooked in design. This becomes an information-loss process of learning about learners, contexts, and processes within the act of design that design research can recapture, which refers to the notion that in the context of both isolated design and research efforts, we do not take advantage of formalizing much of our learning in an exploratory, confirmatory or empirical manner (Bannan-Ritland & Baek, 2008).

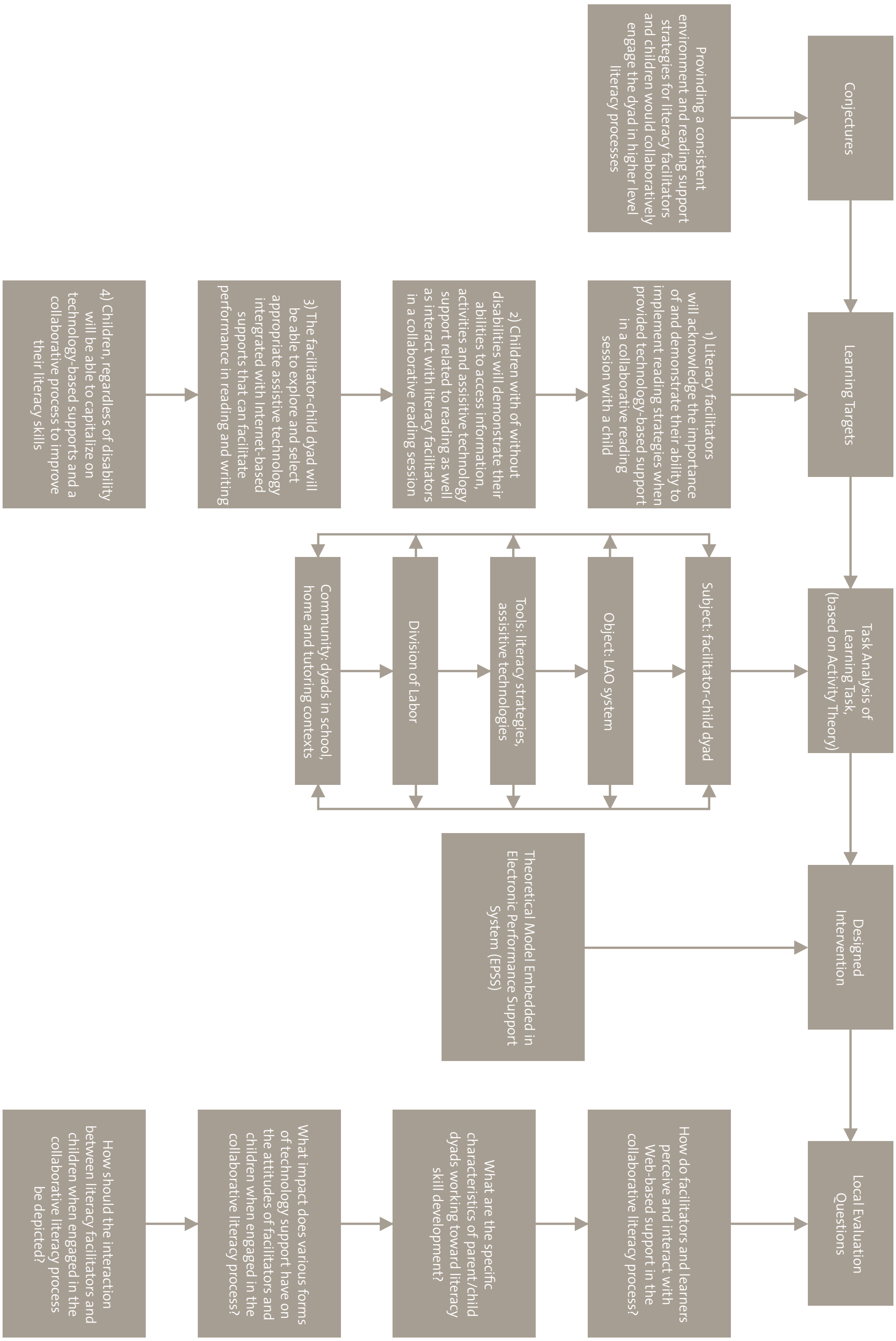


Figure 2: Initial Progressive Formulation from Conjectures to Local Evaluation Questions in LAO

Limitations will certainly also exist for the ILDF framework, as the knowledge generated is only as good as the rigor of the research methods employed. Integrating basic qualitative and quantitative research cycles to inform design at particular points and generate both design principles but also knowledge about learners, learning and learning contexts is the ultimate goal. Limitations may exist in time, quality of information uncovered in data cycles that may impact design, small N to provide mostly qualitative insights initially and the failure inherent in the generation of theory in the discovery research process. However, it is through application in different design research contexts that more formalized processes will begin to be unveiled. The IDLF and LAO example are one case of a few currently for design researchers to uncover the logic and warrants of this new form of research (Kelly, 2006). There are many challenges that remain but capitalizing on the design process to generate research-based data-driven insights is a worthy goal, indeed.

Conclusion

This chapter has presented a brief example and introduction to the ILDF framework that comprises a meta-methodological view of the design research process in an attempt to elucidate common phases and stages in this specific research methodology. The framework is presented to begin to establish common terminology and processes that can promote conscious design research. Most importantly, the ILDF framework is an attempt to provide a roadmap for future design researchers to investigate, articulate, document and inform educational practice.

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References

Akker, J. van den, Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research*. London: Routledge.

Bannan-Ritland, B. & Baek, J. (2008). Investigating the act of design in design research: The road taken. In A. E. Kelly, R. A. Lesh, & J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, mathematics and engineering.* Mahway, NJ: Taylor & Francis.

Cooper, A. (1999). *The inmates are running the asylum: Why high-tech products drive us crazy and how to restore the sanity.* Indianapolis, IN: SAMS.

Collins, A. (1990). *Toward a design science of education. Technical Report Issue No. 1 Center for Technology in Education*. New York, NY. Resources in Education (ERIC) ED 326179.

Collins, A. (1993). *Design issues for learning environments.* Technical Report No. 27 Center for Technology in Education, New York, NY. Resources in Education (ERIC) ED ED357733.

Collins, A. (1999). The changing infrastructure of education research. In E.C. Lagemann & L.S. Shulman (Eds.), *Issues in education research: Problems and possibilities (pp.289-298).* San Francisco: Jossey-Bass.

Confrey, J. & Lachance, A. (2000). Transformative teaching experiments through conjecture-driven research design. In A.E. Kelly & R.A Lesh (Eds.), *Handbook of research design in mathematics and science education (pp.231-265).* Mahway, NJ: Lawrence Erlbaum Associates.

Constantine, L.L. & Lockwood, L. A. (1999) *Software for use: A practical guide to the models and methods of usage-centered design.* Addison, Wesley Longman, Inc.

The Design-Based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher 32(1) 21-24*.

Fishman, B., Marx, R., Blumenfeld, P., Krajcik, J.S. & Soloway, E., (2004). Creating a framework for research on systemic technology innovations. *Journal of the Learning Sciences, 13*(1), 43-76.

Graue, M.E. & Walsh, D. (1998). *Studying children in context.* Thousand Oaks, CA: Sage

Jeffs, T. (2000). *Characteristics, interactions, and attitudes of parent/child dyads and their use of assistive technology in literacy experience on the internet.* Unpublished dissertation, George Mason University, Fairfax, VA.

Jeffs, T., Behrmann, M. & Bannan-Ritland, B. (2006). Asssistive technology and literacy learning: Reflections of parents and children. *Journal of Special Education Technology 21(1), 37-44*.

Kelly, A.E., Lesh, R.A. & Baek, J.Y. (Eds). (2008). *Handbook of Design Research Methods in Education Innovations in Science, Technology, Engineering, and Mathematics Learning and Teaching.* New York: Lawrence Erlbaum Associates.

Kelly, A. E. (2006). Quality criteria for design research. In: J.J.H. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.). *Educational design Research.* London: Routledge.

Kelly, A. E., Baek, J., Lesh, R., & Bannan-Ritland, B. (2008). Enabling innovations in education and systematizing their impact. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

LiteracyAccess Online Phase Four Project Web Site (2000). Retrieved August 30, 2002, from George Mason University, Immersion Program Web Site: http://chd.gse.gmu.edu/immersion/lao/deliver/needs.htm

Rogers, E.M. (2003). *Diffusion of innovations.* New York: The Free Press.

Sabelli, N. (personal communication, May 15, 2002).

Tessmer, M. (1993). *Planning and conducting formative evaluations.* London: Kogan Page.
Tsantis, L. & Castellani, J. (2001). Enhancing learning environments through solution based data mining tools: Forecasting for self-perpetuating systemic reform. *Journal of Special Education Technology, 16(4)*.
Wasik, B. A. (1998). Using volunteers as reading tutors: Guidelines for successful practices. *Reading Teacher,* 51(7), 562-70.
Wittrock, M.C. (1998). Cognition and subject matter learning. In N.M. Lambert and B.L. McCombs (Eds.), *How Students Learn* (pp.143-152). Washington, DC: American Psychological Association.
Zaritksy, R., Kelly, A. E., Flowers, W., Rogers, E., & O'Neill, P. (2003). Clinical design sciences: A view from sister design efforts. *Educational Researcher, 32(1), 32-34*.

4. When is Design Research Appropriate

Anthony E. Kelly

Introduction

Design research has been described in detail in many publications, most recently by the Dutch (Van den Akker, Gravemeijer, McKenney & Nieveen, 2006, with e.g., Kelly, 2006), and the Kelly, Lesh and Baek (2008) collection of papers (e.g., Kelly, Lesh, Baek & Bannan-Ritland, 2008; Middleton, Gorard, Taylor & Bannon-Ritland, 2008). Plomp (chapter 1 of this book) also provides an overview. For that reason, I will not reiterate the description here. Rather, I will assume that the reader is familiar with these sources and the special issues of journals (e.g., Barab & Squire, 2004; Kelly, 2003, 2004) that have appeared.

Instead, I wish to place design research within the frame of a larger context for research on interventions. In her seminal piece, Bannan-Ritland (2003) described a portfolio of research activities using the following categories:

- Informed Exploration
- Enactment
- Evaluation: Local Impact
  - Quasi-experimental designs
  - Randomized trials
  - Hierarchical Linear Modeling
- Evaluation: Broader Impact
  - Implementation in new contexts (Design and Research)
  - Implementation at Scale
  - Scaling up Design and Research
  - Web-enabled proto diffusion
  - Diffusion of Innovations (Rogers)
- Adoption, adaptation, acceptance, rejection

Of course, this larger framework calls for many different research methods. In his paper (Plomp, chapter 1), briefly captures the functions of research methods:

- *survey:* to describe, to compare, to evaluate
- *case studies:* to describe, to compare, to explain
- *experiments:* to explain, to compare
- *action research:* to design/develop a solution to a practical problem

- *ethnography:* to describe, to explain
- *correlational research:* to describe, to compare
- *evaluation research:* to determine the effectiveness of a program

He then provides examples related to the Chinese context:

1. *to describe:* e.g. what is the achievement of Chinese grade 8 pupils in mathematics; what barriers to students experience in the learning of mathematical modelling
2. *to compare:* e.g. what are the differences and similarities between the Chinese and the Netherlands curriculum for primary education; what is the achievement in mathematics of Chinese grade 8 pupils as compared to that in certain other countries
3. *to evaluate:* e.g. how well does a program function in terms of competences of graduates; what are the strengths and weaknesses of a certain approach; etc
4. *to explain or to predict:* e.g. what are the causes of poor performance in mathematics (i.e. in search of a 'theory' predicting a phenomenon when certain conditions or characteristics are met)
5. *to design and develop:* e.g. what are the characteristics of an effective teaching and learning strategy aimed at acquiring certain learning outcomes; how can we improve the motivation of learners.

Both Bannan-Ritland and Plomp provide a broader context for research. Within this larger framework, we may ask, therefore: When is design research appropriate? We may approach an answer by asking, first, when is design research inappropriate?

When is design research inappropriate?

A review of the many published examples of design research (e.g., Kelly, Lesh & Baek, 2008) demonstrate the heavy investment of time and resources necessary to make progress in the face of sometimes daunting circumstances. Design research requires investment of substantial resources at many levels: school district administrators, teachers, students, and the design research team (which may include education researchers, software developers, curriculum specialists, and so forth).
Thus, design research is inappropriate if the educational problem is fairly simple.

If the problem has a known or standard solution, and there is general agreement on when to apply the solution, and the solution has been regularly successfully applied in various settings, design research is probably a poor use of resources.

Even for more chronic learning problems such as reading, if there are adequate training programs, and clear measures of success or progress (e.g., use of phonics to teach decoding skills), design research is probably not indicated. If, however, new research suggests a powerful innovation, design research may be a reasonable choice (see below, and McCandliss, Kalchman & Bryant, 2003)

Generally, design research is probably not recommended for closed problems (e.g., improving mathematics calculation fluency), where the:

- Initial state(s) are known (e.g., two numbers are to be multiplied; a chess board is ready to play).
- Goal state(s) are known (e.g., a product of two numbers is to produced; checkmate or stalemate in chess).
- Operators to move from initial states to goal states are known and can be applied. (e.g., the procedures of multiplication; the rules of chess).

When is design research appropriate?

Design research is recommended when the problem facing learning or teaching is substantial and daunting how-to-do guidelines available for addressing the problem are unavailable. Further, a solution to the problem would lead to significant advances in learning or at least a significant reduction in malfunction in the educational system.

There should be little agreement on how to proceed to solve the problem, and literature reviews together with an examination of other solutions applied elsewhere (i.e., benchmarking) should have proven unsatisfactory.
Design research is further suggested if prior training or interventions have consistently proven unsuccessful. Design research is often indicated for critical educational goals, even when there is not a clear definition of success, or designing adequate indicators of success is part of the overall problem.

In other words, design research is most appropriate for *open*, or more appropriately, wicked problems. The concept of a wicked problem was described by Rittel and Webber (1977) to describe problems that share the features of open problems, but that also engage elements that make their solution frustrating or potentially unattainable.

Following from the description of closed problems, above, in open problems, some or more of the following apply:

- Initial state(s) are unknown or are unclear.
- Goal state(s) are unknown or are unclear.
- Operators to move from initial states to goal states are unknown or how to apply the operators is unclear.

For wicked problems (e.g., Camillus, 2008; Horn & Weber, 2007; Richey, 2007), the character of open problems pertain. Plus, there are typically inadequate resources, unclear "stopping rules" (conditions that indicate a solution is at hand or the project should be abandoned), unique and complex contexts, and inter-connected systemic factors that impinge on progress. Most frustrating, these other factors may themselves be symptoms of problems of associated wicked problems. For example, attempting to teach numeracy in a society with high poverty and HIV rates.

Therefore, one of the broad goals of design research is to dynamically clarify the initial and goal states and the operators, and to illuminate the nature of the problem – i.e., to "tame" a wicked problem by better specifying its character and making it open to intervention. In educational settings, design research is recommended when one or more of the following conditions operate to make the problem more wicked and open than simple and closed, for example:

- When the *content knowledge* to be learned is *new or being discovered even by the experts.*
- When how to teach the content is unclear: *pedagogical content knowledge is poor.*
- When the *instructional materials* are *poor* or not available.
- When the *teachers' knowledge* and *skills* are *unsatisfactory.*
- When the *educational researchers' knowledge* of the content and instructional strategies or instructional materials are *poor.*
- *When complex societal, policy or political factors may negatively affect progress.*

A number of examples of may be found in Kelly, Lesh and Baek (2008). Some other examples from mathematics, science, and reading are briefly presented in the next section.

Examples from mathematics, science and reading

This section presents briefly a number of examples of when applying design research is the appropriate research approach.

1. **Introducing Existing Science or Mathematics at Earlier Grade Levels**
For example, some education authorities have advocated the teaching of algebra in earlier grades (as early as the 8th grade in the US), see Foundations for Success: Report of the National Mathematics Advisory Panel (http://www.ed.gov/about/bdscomm/list/mathpanel/index.html). A few policymakers have even advocated starting algebra instruction in the early elementary.

How should one proceed to introduce ideas of algebraic reasoning in the early elementary grades? Is this recommendation advisable? This issue clearly meets the criteria set out, above. Some of the complexities associated with answering this question can be gauged by reading some of the recent work on this topic by Carraher and colleagues (e.g., Carraher & Schliemann, 2007; Carraher, Schliemann, & Schwartz, 2007; Peled, & Carraher, 2007; Schliemann, Carraher & Brizuela, 2007).

2. **Learning new or emerging science content (e.g., genetics)**
Research in microbiology is in revolution with stunning findings appearing on front pages of newspapers, almost daily, worldwide. How can historical science education be updated to prepare high school teachers and students to meet this challenge and opportunity? Moreover, how can high schools prepare students to be successful in emerging integrated biology programs such as the one at Princeton University (http://www.princeton.edu/integratedscience/)?
Rutgers University has explored this challenge through its microbiology program (http://avery.rutgers.edu/WSSP/Begin/index.html). A review of its varied solutions to this challenge exemplifies this rich context for design research.

3. **Uncovering the Potential Contributions of Neuroscience for Mathematics Learning**
The author has joined other writers (e.g., Varma, McCandliss & Schwartz, 2008) in outlining the case for cultivating the intersection of neuroscience and mathematics learning. (e.g., Kelly, 2002, 2008).

Why is there a growing interest in neuro-mathematics education? A number of factors have coincided to support a surge in interest in brain-based mathematics education research (see OECD, 2007 for a comprehensive review of brain-related research in education):

- Confidence due to recent gains in understanding the brain bases for processes of decoding in reading.
- Emergent findings in the neural bases for mathematical thought.
- Decades of behavioral and cognitive science findings on learning mathematics and related higher-order processes from which to draw.

- A desire to disambiguate and constrain research hypotheses at the behavioral, cognitive and social levels of analysis.
- A desire to sharpen and ground diagnosis and remediation of mathematical learning difficulties with improved assessments.
- A desire to construct new mixed-methods research methodologies for the social sciences.
- A desire to scientifically debunk learning and teaching "neuromythologies".
- A sense of urgency to bring scientific discourse, evidence and reasoning to the slate of ethical issues that are emerging that pertain both to learning and teaching.
- A goal to improve methods of teaching of mathematics.
- A goal to improve educational materials, including those that use computer hardware and software.
- More comprehensive and testable models of learning emerging from cognitive science (e.g., Bruer, 1997).
- A desire to understand and promote significant mathematical creativity.
- To challenge neuroscientists to continue to push the boundaries of imaging technologies, and to co-formulate clinical learning tasks.

The point to be drawn here is that the coincidence of these factors, alone, does not dictate teaching or learning strategies or even provide principles, materials, curricula, interventions, or assessment approaches to support either learning or teaching. How, then, should researchers proceed to bring the laboratory findings of cognitive neuroscience into the classroom in viable ways? Again, the problem meets the above requirements for using design research.

4. Cyberinfrastructure

Cyberinfrastructure encompasses the use of distributed internet resources such as computing systems, data, information resources, networking, digitally enabled-sensors, instruments, virtual organizations, and observatories (NSF, 2007). It allows to link groups of scientists to attack multi-level complex problems. These problems will have associated challenges for learning, teaching, and assessment.

Important questions are how education should capitalize on cyberinfrastructure resources. What it means to study science content within a cyberinfrastructure framework, and what the curricular, instructional design, assessment, teacher professional development, and policy questions that are raised, and how they must be answered to fully exploit the high-technology investment in science at this level. As important, what are the methodological challenges in studying learning within a cyberinfrastructure project? For example, how are claims of causality handled in a complex networked and nested learning environment, and what evidence would make such claims credible (e.g., Kelly & Yin, 2007)? This is a clear example, spanning many science disciplines, for which design research is an appropriate investment.

The Appendix to this chapter discusses in more detail the meaning and possibilities of cyberinfrastructure or e-science in general and for education.

5. Reading and Inquiry Science

The reader's attention is drawn to two examples from Brenda Bannan-Ritland, currently at George Mason University. Her analysis of how design research works within her integrative learning design framework (Bannan-Ritland, 2003; Bannan-Ritland & Baek, 2008; see also paper in this volume) provides examples in narrower, if no less important, applications.

For example, design research is appropriate when developing creative or innovative educational products, blueprints or designs that are directed at chronic educational problems. In a number of papers (see LiteracyAccess Online, Bannan-Ritland & Baek, 2008; http://immersion.gmu.edu/lao/spring2003/projectResources.htm), and Bannan-Ritland's chapter (this volume) describes the processes undertaken to address a chronic problem in most countries, how to teach reading to struggling readers.

Following her work on LiteracyAccess Online, Bannan-Ritland extended her work on reading design into the learning of inquiry science at the 4th grade. Based on this experience, Bannan-Ritland significantly added to the broadening use of design research principles by methodologically incorporating teachers as designers in the overall design research paradigm. This exciting new direction, called teacher design research (which dovetails with work by Zawojewski et al., 2008), is described in Bannan-Ritland (2008). The area of application in the report is earth sciences in the early elementary school.

The growing need for design assessment research

A recent review of contributions to design research show an increasing awareness of the need for tackling the problem of how to assess learning in emerging areas of learning, particularly when there is an emphasis on innovation in instructional practices (Kelly, Baek, Lesh & Bannan-Ritland, 2008). They note:

> **In design research as currently practiced, assessment is not directed at some summative sense of learning, though a summative measure of student learning would be central to later attempts at confirmatory studies, i.e. to show local impact (Bannan-Ritland, 2003). . . . Design research also differs from formative assessment with regard to the student's knowledge end state and how feedback loops are enacted. Formative assessment is the gathering of data relative to some predetermined fixed point, providing feedback that informs the students and teacher of their current knowledge state in relation to some**

end state (see Black & Williams, 1998). In design research, assessment may be used formatively in order to dynamically determine progress toward mastery of disciplinary knowledge (e.g., Cobb & Gravemeijer, [Kelly, Lesh & Baek, 2008]) or to guide the design of a prototype and to inform its iterative re-design as necessary or both. In fact, sensitivity to assessment practices themselves may inform changes to the act of assessment itself (e.g., Lobato, [Kelly, Lesh & Baek, 2008]; Lesh et al., [Kelly, Lesh & Baek, 2008]). Ultimately, design researchers are challenging the assumptions about learning, teaching, and knowing that underlie available assessment techniques, not only in terms of the psychometric assumptions (like item response theory), but also the function of assessment itself within and across the stages of design research (see Sloane & Kelly, [Kelly, Lesh & Baek, 2008]).

In other words, when a suitable context for design research is identified, to the extent that the application is novel (e.g., teaching algebraic concepts in the early elementary grades, reading comprehension) or the knowledge unfolding (e.g., genomics, cyberinfrastructure), there will be a requirement and a responsibility for researchers not only to iteratively investigate the impact of learning prototypes, but also to address directly the question of how this impact will be measured. The point here is not that assessment is necessary, rather that the targets for assessment may arise dynamically in the course of design research and measures may not be available apriori. As a result, many of the questions about the validity and reliability of measures have to be actively reconsidered. In practice, too often, prototypes are redesigned without specifying the evidence base (via assessment design) for the redesign. In many cases, design researchers appear to rely on judgment or subjective factors. Adding to the unfolding need for new methods in design assessment will be a major challenge and opportunity for scholars in the next decade (e.g., Kelly, 2005a, 2005b).

What is the *evidence* to support claims of effectiveness during iterations, and later, as the innovation is subject to more rigorous tests?

Design research in general practice

The goal of this chapter was to characterize design research at a broad level, and to provide some examples of where the significant resources associated with design research might be spent. I will finish with a general outline of how design research cycles unfold within a larger framework of research (Bannan-Ritland, 2003; Plomp, this volume). Using cognitive science, cognitive psychology and other social science methods such as surveys, case studies, clinical interviews, ethnography:

- Identify or characterize the initial states. Clarify the initial knowledge and goal knowledge states (of students, teachers, researchers, experts) using the interventions.
- Identify or characterize the goal states. Design formative assessments to monitor progress toward the goal state.
- Identify or characterize the operators. Dynamically using the cognitive and other analyses, iteratively design and specify the operators (interventions, supports, environments) to support learning. See, in particular, the work of Bannan-Ritland (2008) and Zawojewski et al., (2008).
- Inform re-design cycles or iterations using data gathered from unfolding, and parallel work in design assessment.
- Work toward developing a mature prototype that can be subject to a more definitive test (e.g., randomized clinical trial), see Bannan-Ritland's (2003) local impact phase.

One final note: Prototyping and theory building

By perturbing the system using the interventions in this iterative research process, design research transcends each of the local methods used. In other words, design research involves not only the use of different methods (e.g., surveys, case studies, clinical interviews), but combines the fruits of each method, over time, to specify theory and models related to learning, teaching and assessing the target knowledge (see Cobb & Gravemeijer, 2008). Thus, design research *goes beyond simple development of an intervention* and *goes beyond standard cognitive analyses* and allows theory and modeling that accounts for the content, the cognition, and the enactment by real people in real and rich contexts with real limits on resources (see Zaritsky et al., 2003).

The question of the "theoretical yield" of design research is not a simple one. Note that this chapter was framed in terms of complex, open and wicked problems. For such problems, there exists no simple theoretical model (at least none is perceived at the time). For that reason, if "theory" is something that is assumed to be informed by hypothesis testing of a somewhat definitive question, then design research (in early stages) will likely not pose or easily answer simple hypotheses, and thus not have simple theoretical yield. Schwartz, Chang and Martin (2008; in Kelly, Lesh & Baek) views the design research cycles as preparatory for theoretical yield from later randomized clinical trials or other laboratory tests. If the observation is borne out that much of educational intervention occurs in complex systems, then the theoretical yield will not be associated with one theory, but many (perhaps interdependent) subtheories. If so, then the yield may be diffuse and obfuscated by the influence of many factors that are not controlled in design research settings. Some researchers have attempted to frame design research within an overarching theory (say, "variation" theory, Holmqvist, Gustavsson, & Wernberg, 2008). The pay-off of this approach will inform us greatly about the role of theory in design research.

Some writers use the word "theory" more generally to encompass "design principles," and it may be the case that such principles can indeed be identified (see Kali, 2008). Such recommendations for design practice are useful heuristics. If these heuristics show evidence of durable applicability across many projects and contexts, it is likely that some necessary (as opposed to contingent) principles are being evoked (see Kelly, 2004), which would open these heuristics to theoretical analysis.

References

Akker, J.J.H. van den, Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds.) (2008). *Educational design Research.* London: Routledge.

Bannan-Ritland, B. (2003). The role of design in research: The integrative learning design framework. *Educational Researcher 32(1) 21-24*.

Bannan-Ritland, B. (2008). Teacher design research: An emerging paradigm for teachers' professional development. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

Bannan-Ritland, B. , & Baek, J. Y. (2008). Investigating the act of design in design research. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

Barab, S. & Squire, K. (2004). Design-based research: putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1-14.

Camillus, John C., "Strategy as a Wicked Problem," Harvard Business Review, May 2008.

Carraher, D.W. & Schliemann, A. D. (2007). Early algebra and algebraic reasoning. In F. Lester (ed.) *Second handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics.* Vol II. Charlotte, NC: Information Age Publishing, pp. 669-705.

Carraher, D.W., Schliemann, A.D. & Schwartz, J. (2007). Early algebra is not the same as algebra early. In J. Kaput. D. Carraher, & M. Blanton (Eds.), *Algebra in the early grades.* Mahwah, NJ, Erlbaum, pp. 235-272 (now Taylor & Francis).

Chin, G., Jr., & Lansing, C. S. (2004). Capturing and supporting contexts for scientific data sharing via the biological sciences collaboratory, *Proceedings of the 2004 ACM conference on computer supported cooperative work*, 409-418, New York: ACM Press.

Cobb, P. & Gravemeijer, K. (2008). Experimenting to support and understand learning processes. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

Cogburn, D. L. (2003). HCI in the so-called developing world: what's in it for everyone, *Interactions*, 10(2), 80-87, New York: ACM Press.
Holmqvist, M., Gustavsson, L., & Wernberg, A. (2008).
Variation theory: An organizing principle to guide design research in education. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.
Horn, Robert E., *Knowledge Mapping for Complex Social Messes*, a presentation to the "Foundations in the Knowledge Economy" conference at the David and Lucile Packard Foundation, July 16, 2001.
Kali, Y. (2008). The Design Principles Database as means for promoting design-based research. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.
Kelly, A.E. (2003). The role of design in research. *Educational Researcher, 32*(1), 3-4. Theme issue guest editor.
Kelly, A. E. (2004). Design research in education: Yes, but is it methodological? *Journal of the Learning Sciences, 13*(1), 115-128.
Kelly, A. E. (2005a). *"How do modeling perspectives inform program assessment?"* Presentation at the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Roanoke, VA.
Kelly, A. E. (2005b). "The intersection of design and assessment for mathematics learning." Presentation, National Science Foundation Workshop, Park City, UT.
Kelly, A. E. (2006). Quality criteria for design research. In: J.J.H. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.). *Educational design Research.* London: Routledge.
Kelly, A. E. (2008). Brain research and education: Potential implications for pedagogy. In *Education, sciences cognitives et neurosciences.* Paris: Presses Universitaries de France.
Kelly, A. E., Baek, J., Lesh, R., & Bannan-Ritland, B. (2008). Enabling innovations in education and systematizing their impact. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.
Kelly, A. E. & Yin, R. (2007). Strengthening structured abstracts for educational research: The need for claim-based structured abstracts. *Educational Researcher.* 133-138.
McCandliss, B. D., Kalchman, M., & Bryant, P. (2003). Design experiments and laboratory approaches to learning: Steps toward collaborative exchange. *Educational Researcher, 32*(1), 14-16.
Middleton, J., Gorard, S., Taylor, C., & Bannan-Ritland, B. (2008). The "compleat" design experiment: From soup to nuts. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

National Science Foundation (2007). *Cyberinfrastructure vision for 21st Century discovery.* Office of Cyberinfrastructure. March.

OECD (2007). *Understanding the brain: The birth of a learning science.* Paris: OECD.

Olson, G.M., Teasley, S., Bietz, M. J., & Cogburn, D. L. (2002). Collaboratories to support distributed science: the example of international HIV/AIDS research, P*roceedings of the 2002 annual research conference of the South African institute of computer scientists and information technologists on enablement through technology,* 44–51.

Peled, I. & Carraher, D.W. (2007). Signed numbers and algebraic thinking. In J. Kaput. D. Carraher, & M. Blanton (Eds.), *Algebra in the early grades*. Mahwah, NJ, Erlbaum, pp. 303-327 (now Taylor & Francis). [608 k]

Richey, Tom; *Wicked Problems: Structuring Social Messes with Morphological Analysis,* Swedish Morphological Society, last revised 7 November 2007

Schliemann, A.D., Carraher, D.W., & Brizuela, B. (2007). *Bringing out the algebraic character of arithmetic: From children's ideas to classroom practice.* Lawrence Erlbaum Associates (now Taylor & Francis).

Schwartz, D. L., Chang, J., & Martin, L. (2008). Instrumentation and innovation in design experiments: Taking the turn towards efficiency. In A. E. Kelly, R. Lesh, and Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

Thomas, J. J., & Cook,, K. A. (Eds.), (2005). *Illuminating the path: The research and development agenda for visual analytics.* Los Alamitos, CA: IEEE Computer Society.

Varma, S., McCandliss, B. D., Schwartz, D. L. (2008). Scientific and pragmatic challenges for bridging education and neuroscience. *Educational Researcher, 37*(3), 140-152.

Wulf, W. (1989, March). The national collaboratory. In *Towards a national collaboratory.* Unpublished report of a National Science Foundation invitational workshop, Rockefeller University, New York.

Zaritksy, R., Kelly, A. E., Flowers, W., Rogers, E., & O'Neill, P. (2003). Clinical design sciences: A view from sister design efforts. *Educational Researcher, 32*(1), 32-34.

Zawojewski, J., Chamberlin, M., Hjalmarson, M. A., & Lewis, C. (2008). Developing design studies in mathematics education professional development: Studying teachers' interpretive systems. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching.* New York: Routledge.

Appendix

For the US National Science Foundation (NSF, 2007), the opportunities in the complementary areas that make up cyberinfrastructure: computing systems, data, information resources, networking, digitally enabled-sensors, instruments, virtual organizations, and observatories, along with an interoperable suite of software services and tools provide challenges along three lines: (a) data, data analysis, and visualization; (b) virtual organizations for distributed communities; and (c) learning and workforce development.

A major parallel activity in cyberinfrastructure is underway in Europe, which is labeled "e-science". e-science describes similar activities to the US cyberinfrastructure. Not unlike early visions of US cyberinfrastructure, the UK launching document, (http://www.nesc.ac.uk/documents/OSI/report.pdf), did not explicitly list education as one of the key areas of concern in setting up a cyber infrastructure. It focused, rather, on networks, middleware, digital libraries, and computational resources. As in the US, this imbalance is being recognized. In Europe, it being addressed by the creation of ICEAGE: "The international collaboration to extend and advance grid education" (http://www.iceage-eu.org/v2/partners.cfm). ICEAGE, while international, is primarily a European effort, with branches in Edinburgh, Scotland, University of Catania, Sicily, SPACI (Southern Partnership for Advanced Computational Infrastructures), an Italian university-based effort (http://www.spaci.it/), CERN, near Geneva (http://public.web.cern.ch/Public/Welcome.html), the Royal Institute of Technology in Sweden (http://www.kth.se/?l=en_UK), and The Computer and Automation Research Institute, Hungarian Academy of Sciences (http://www.sztaki.hu/institute).

Cyberinfrastructure describes the use of distributed internet resources to link groups of scientists to attack multi-level complex problems. These problems will have associated challenges for learning, teaching, and assessment. For example, a design research problem would be how to describe and credit a student's learning in a cyberinfrastructure research collaboratory in geosciences:
Scientifically, a crucial concern in detecting earthquakes is to measure minute changes in elevation. Traditional radar, which uses radio waves as the means of detecting distances from the source, are of limited value in precise measurements due to the length of the radio waves. The use of LiDAR (Light Detection and Ranging) technology allows the use of wavelengths in the ultraviolet, visible, or near infrared range (from about 10 micrometers to the UV (ca. 250 nm). These shorter wavelengths allow detection of smoke and other diffuse particulates, which has led to the use of LiDAR in meteorology.
For earthquake prediction, LiDAR can be used to locate faults, and to measure uplift. Faults describe the line of fracture and demarcation between plates (McKnight & Hess, 2000).

Uplift is typically due to tectonic plate activity (Kearney & Vine, 1990), technically "orogenic uplift" or due to the removal (due to erosion) of heavy material, technically "isostatic uplift." The significant advantage of LiDAR over radar is that LiDAR can generate digital elevation models (DEMs) of the shape the earth's surface at resolutions not previously possible. Complexifying the problem, an earthquake is sometimes associated with volcanic activity. For example, the "Pacific Rim of Fire" is associated with colliding tectonic plates. In such cases, LiDAR may be used not only to make precise measurements of elevation, but also to characterize the density and even the chemical makeup of the gases and ash emitted by a volcano. LiDAR data on Mount St. Helen's volcano may be found at http://wagda.lib.washington.edu/data/type/elevation/lidar/st_helens/.

Learning about geomorphology using LiDAR is complex, and some publicly available web sites have attempted to provide instruction (e.g., http://lidar.cr.usgs.gov/ and http://gisdata.usgs.net/website/lidar/viewer.php). The most comprehensive activity has been conducted by the GEON network (http://www.geongrid.org/). This network is part of a cyberinfrastructure research collaborator. Tutorials on the use of LiDAR within and outside of geoscience (e.g., coastal erosion, flooding, river courses, forest mapping and mining) may be found here; http://home.iitk.ac.in/~blohani/LiDAR_Tutorial/Airborne_AltimetricLidar_Tutorial.htm.

We can now see just a fraction of the associated scientific concepts that are pertinent in understanding the use of LiDAR in understanding geoscience: e.g., radar technology vs LiDAR technology, the science of plate tectonics, digital elevation models, reading and understanding computer visualizations, modeling complex inter-related scientific processes, reasoning about implications for human activity, including urban growth, and so forth. Which of these (or other related concepts) are most pertinent for scientists in a cyberinfrastructure research collaboratory will be an empirical question. How to identify the central constructs pertinent to a high-school science education will provide a significant measurement challenge, including how to design authentic assessments to measure understanding of these concepts. Identifying and mapping out the content and cognitive demands of such measurement could be a major focus of the design research work. Of particular interest will be how to establish content, construct, predictive, concurrent and other forms of validity for these measures.

Factors converging to support the development of cyberinfrastructure.

1. Existing computing data grids in the US and overseas
   a. The TeraGrid project (http://www.teragrid.org/about/) combines the power of NCSA, SDSC, Argonne National Laboratory, CACR, PSC, ORNL, TACC, and various university

partners integrated by the Grid Infrastructure Group at the University of Chicago. European e-science links facilities on the Continent with those in the UK. Similar activities occur in Japan. Industry partners include IBM, Intel, Hewlett-Packard and Oracle.

2. The availability of massive data storage capacity and speed
    a. The TeraGrid currently offers over 100 teraflops of computing power; and over 3 petabytes of rotating storage
3. The development of middleware and software to gather and analyze stored data
    a. The TeraGrid supports data analysis and visualization production interconnected at 10-30 gigabits/second.
4. The emergence of large teams of scientists dedicated to solving shared science problems (acting through science "collaboratories" and "gateways")
    a. A collaboratory (Wulf, 1989) is "more than an elaborate collection of information and communications technologies; it is a new networked organizational form that also includes social processes; collaboration techniques; formal and informal communication; and agreement on norms, principles, values, and rules" (Cogburn, 2003, p. 86). Collaboratories exist in many areas of science, including biology, chemistry, geoscience and astronomy (e.g., Chin & Lansing, 2004; Olson, Teasley, Bietz, & Cogburn, 2002).
    b. Science gateways are web-based portals or interfaces for the structures and data of the cyberinfrastructure in many science areas (for a listing of 24 gateways, see http://www.teragrid.org/programs/sci_gateways/).
5. Developments in scientific visualization.
    Scientific visualization draws on human spatial and visual processing in order to model and analyze computationally intense the graphic display of complex data (for a comprehensive review, see Thomas & Cook, 2005). Existing methods and models for scientific visualization are significantly challenged by cyberinfrastructure (e.g., http://www.teragrid.org/userinfo/data/vis/vis_gallery.php; Chin et al., 2006).
6. Funding.
    The establishment and funding of national and international efforts to coordinate and develop the infrastructure to better serve science and, more recently, education (e.g., the Office of Cyberinfrastructure – NSF; CERN, Dutch (VL-e) and UK initiatives). The promise of cyberinfrastructure for education is that the vast investment by US agencies (upwards of $250M over the next 5 years, alone) will provide test-beds for exploration.


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5. Formative Evaluation in Educational Design Research

Nienke Nieveen

Introduction

In this chapter and in line with the general introduction of this book, we define educational design research as: *the systematic study of analyzing, designing and evaluating educational interventions in order to solve complex educational problems for which no ready-made solutions are available and to gain insight in key design principles.* Design research projects strive after two types of main results. The first aim comprises high-quality interventions (such as programs, products and processes) designed to solve complex educational problems. This type of output puts forward the practical relevance of design research. It is for that reason that design research is also labeled as being use-inspired, applied oriented and/or socially responsible research (van den Akker, 1999; Reeves, 2000).
The second main output of design research is the accompanying set of well-articulated design principles (Linn, Davis & Bell, 2004; van den Akker, 1999) that provide insight in the:

- purpose/function of the intervention;
- key characteristics of the intervention (substantive emphasis);
- guidelines for designing the intervention (procedural emphasis);
- its implementation conditions;
- theoretical and empirical arguments (proof) for the characteristics and procedural guidelines.

These comprehensive design principles serve several purposes for a variety of target groups. From a research perspective, these principles show the contribution of design research to the existing knowledge base with information on how the intervention works in practice, the effects of using the intervention and explanation of the working mechanisms. For educational designers, these principles carry rich information on how to design similar interventions for similar settings. From the perspective of future users, the principles provide information needed for selecting and applying interventions in the specific target situation and provide insights in the required implementation conditions. Finally, for policy makers, these principles assist in making research-based decisions for solving complex educational problems.

In order to reach both types of output (high quality interventions and design principles), design researchers carefully combine design and research activities resulting in an iterative development approach. In this contribution we will first explore this iterative nature of design research (here labeled with the term prototyping approach) and then elaborate on the role that formative evaluation plays in design research projects in order to optimize interventions and design principles. The contribution will end with some remarks on the role of design researchers concerning formative evaluation activities.

Prototyping approach

Design research is by nature highly iterative (Design-based research collective, 2003; van den Akker, 1999). Each iteration helps to improve *prototypes* of both end results of design research efforts: 1. the educational intervention under development; and 2. its accompanying tentative design principles. This section discusses briefly the notion of an iterative or prototyping approach.

A prototype is a preliminary version of the whole or a part of an intervention before full commitment is made to construct and implement the final product. Prototypes may be used in two ways (cf. Smith, 1991). On the one hand, a prototype may be continually refined (based on formative evaluation results and reflections of developers on the prototype) and evolve towards a final deliverable. This refining approach can be referred to with the term *evolutionary* prototyping.
On the other hand, developers can design *throw-away* prototypes, such as scenarios or paper-based mock-ups (Nieveen, 1999). A scenario is a narrative description of typical and critical situations that prospective users participate in. Scenarios may be used to make the tentative design specifications more concrete. This makes it easier to communicate the potentials of a system with the target group. A paper-based mock-up comprises a pile of papers representing all screens which may appear during the use of the intervention. This kind of prototype is often used in software development projects. Users may 'walk through' the screens to get an idea of the intentions of the software application. Paper-based prototypes focus the attention of the user more on content and overall structure than on appearance. After being evaluated, a throw-away prototype will be discarded and its evaluation results are taken into account in the next prototype. This process will continue until all uncertainties are covered and the final product or intervention can be delivered.

Especially in design research projects that aim at innovative and complex products, with few experiences or design principles from which to draw, such a prototyping approach (either evolutionary or throw-away) is recommendable. Some design research projects combine both kinds of prototypes, for instance by first designing and evaluating throw-away prototypes and then shifting to an evolutionary approach (Nieveen, 1999).
To make the prototyping approach with throw-away and/or evolutionary prototypes feasible, the notion of 'think big, but start small' is helpful. By first developing a small part of the proposed intervention, one keeps the development process manageable and one can

learn from failures and apply successes when designing the subsequent parts. In order to keep an overview on the entire development process it is often functional to decompose the intervention into several components that could be built separately. Educational interventions can be decomposed into at least two key aspects which will require major attention during the design process (cf. Nieveen, 1999; Nieveen & van den Akker, 1999):

- the *conceptual framework* of the intervention, referring to all notions that are underlying the intervention. In case of an educational intervention, it refers for instance to the conceptualization of all 10 curriculum components presented in the curricular spiderweb (van den Akker, 2003);
- the *presentation-mode* of the intervention, referring to the format that assures that the intervention is usable for its users. To assist users finding the content of their preference, all interventions (paper-based and computer-based) need a sound user-interface including consistent layout and transparant navigation.

The various conceptual and presentation elements may be in different stages of development in each prototype. However, towards the final deliverable, all elements need to be consistent with one another. For example, in a math project aimed at solving problems of low-achieving students with measuring quantities, interventions were developed to help these students to acquire the required mathematical problem solving skills. The design research team put much emphasis on the development of innovative learning and teaching activities (two components of the curricular spiderweb/the conceptual framework) geared to the problems of these students. Subsequently, the first version of the lesson materials was designed according to this specific pedagogy. During the formative evaluation of this first prototype, the design research team was especially interested in the quality of the new learning and teaching activities (being part of the conceptual framework) and less in the layout (being part of the presentation-mode). However, towards the end of the study, the layout of the materials got specific attention in order to improve the overall practicality of the materials.

Formative evaluation

In a prototyping approach empirical data are needed to gain insight into the quality of the tentative intervention and design principles. For that reason, formative evaluation is a crucial feature of each prototyping approach and thus of each design research project. It provides insight in the potentials of the intervention and its key characteristics. Results of the formative evaluation give ground for both 1. improving the prototype of the intervention towards a high-quality final deliverable and 2. sharpening the underlying tentative design principles towards an elaborated set of design principles. In this way, each prototyping cycle contributes to successive approximation of both outputs of a design research project. In the Generic Design Research Model of Wademan (2005), see Figure 1, this is nicely illustrated in the prototyping and assessment phase.

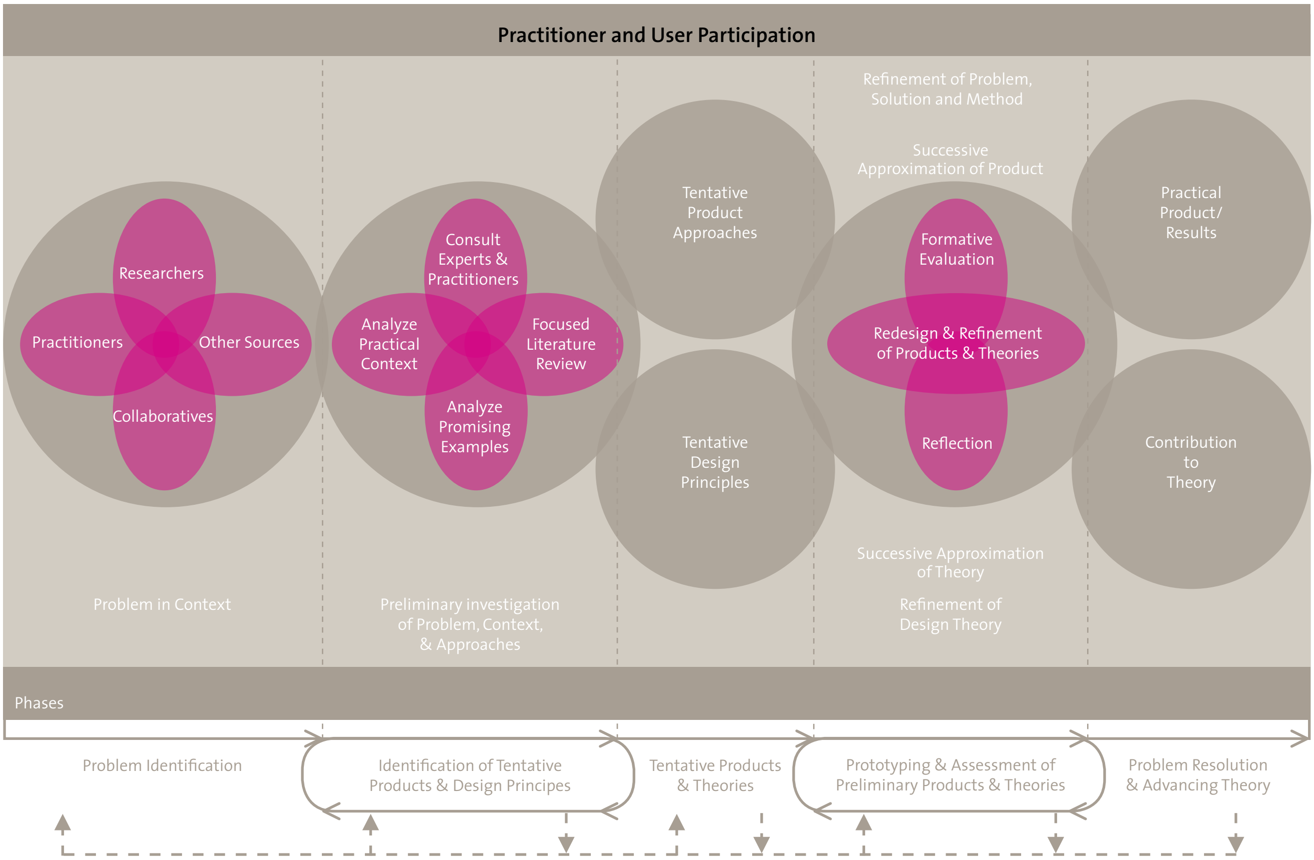

Figure 1: Generic Design Research Model (Wademan, 2005)

In this section, the concept of formative evaluation will be further elaborated and placed in a design research context. As far as the term *evaluation* is concerned, the Joint Committee on Standards for Educational Evaluation (1994) uses the following definition: "Evaluation is the systematic assessment of the worth or merit of some object." Merit refers to the object's inherent, intrinsic value, while its worth is defined as its contextually determined, place-bound value (Lincoln & Guba, 1979). Scriven (1967) was the first author who made the distinction between formative and summative evaluation. Formative and summative evaluations serve different functions. The function of *formative evaluation* is 'to improve'. It focuses on uncovering shortcomings of an object during its development process with the purpose to generate suggestions for improving it. The function of *summative evaluation* is 'to proof'. A summative evaluation is carried out to gain evidence for the effectiveness of the intervention and find arguments that support the decision to continue or terminate the project. Summative evaluations are being carried out without the direct intention to reveal points of improvement. However, it is not always possible to draw a sharp line between formative and summative evaluation. The results of summative evaluations are usually taken into account while developing a second release of the product.

Based on comparing and synthesizing definitions of various scholars in the field of formative evaluation (cf. Brinkerhoff, Brethouwer, Hluchyj & Nowakowski, 1983; Flagg, 1990; Scriven, 1967, Tessmer, 1993) we define formative evaluation in the context of design research as: *a systematically performed activity (including research design, data collection, data analysis, reporting) aiming at quality improvement of a prototypical intervention and its accompanying design principles.*
As stated before, a design research project usually needs several iterations before an optimal solution for the complex problem can been reached. Each design research cycle or iteration concentrates on specific research questions and needs an appropriate research design. The remainder of this section will elaborate on issues related to the research design of formative evaluation activities.

Formulating research questions
The main research question of a formative evaluation is built around the kind of value judgment that is expected from evaluating the prototype and two key attributes of the prototypical intervention: 1. the stage of development of the prototype; and 2. the main element of the prototype that the evaluation will focus on.

First of all, it is necessary to make clear the type of value judgment that the evaluation needs to result in. In this respect, we distinguish four quality criteria that are applicable to a wide array of educational interventions (see Table 1). At the end of a design research project, the intervention should suffice all of these criteria. However, usually each iteration concentrates on one or two of these criteria.

Criterion	
Relevance (also referred to as content validity)	There is a need for the intervention and its design is based on state-of-the-art (scientific) knowledge.
Consistency (also referred to as construct validity)	The intervention is 'logically' designed.
Practicality	**Expected** The intervention is expected to be usable in the settings for which it has been designed and developed. **Actual** The intervention is usable in the settings for which it has been designed and developed.
Effectiveness	**Expected** Using the intervention is expected to result in desired outcomes. **Actual** Using the intervention results in desired outcomes.

Table 1: Criteria for high quality interventions

It is important to point here to the distinction between *expected* and *actual* practicality and effectiveness. Only when the target users have had practical experience with using the intervention one will be able to get data on the *actual practicality* of the prototype. Similarly, only when target users have had the opportunity to use the intervention in the target setting, the evaluator will get data on the *actual effectiveness*. In all other instances, such as a group discussions based on the materials, the researcher will only get data on the *expected practicality and/or effectiveness.*

Moreover, when preparing a formative evaluation it is important to describe the boundaries of the prototype that will be evaluated. In a design research project a (throw-away or evolutionary) prototype is usually in one of the following development stages:

- Design specifications: A first and general description of the intervention in which attention is paid to its substantive parts. This sketch has been based on preliminary research activities (including problem and context analysis and literature review).
- Global intervention: Some or all components of the intervention are given some detail. This could be termed as a horizontal prototype. It gives an idea of how the intervention will eventually appear, however it cannot yet be used in practice. For example, in the case of the development of a new curriculum at this stage the intervention could take the form of a table of contents with a brief description of sub-components or modules.
- Part of the intervention in detail: At this stage, a part or component of the intervention has been elaborated to a concrete level for use by the target group. This could be called a vertical prototype. One can imagine various sub-stages with each of them addressing only a specific part of the total intervention for use in practice.

- Complete intervention: The total intervention is sufficiently detailed that it could be used in the intended user-setting.

Another issue that needs to be clear before starting a formative evaluation is the main elements of the prototype that the evaluation will focus on. These can be all or one elements related to the conceptual framework and presentation-mode of the intervention.

The three characteristics (quality criteria, elements and the stage of development) give input for the main research questions. The syntax of these research questions is: 'What is the [quality criterium a, b, c and/or d] of [element of the conceptual framework or presentation mode] of the intervention that is in [development stage w, x, y, z]. Instances of these questions are:

- What is the relevancy [quality criterium] of the content [conceptual element] of a quick reference manual for using Chinese characters that is in a global stage [development stage]?
- What is the internal consistency [quality criterium] of the attainment targets [conceptual element] for science in upper secondary education of which three out of seven domains are elaborated in detail [development stage]?
- What is the practicality [quality criterium] of the layout [element of presentation mode] of the Math text book modules that is in a completed stage [development stage]?

Selecting appropriate methods

Design researchers need to select those formative evaluation methods that fit the research questions. Building on earlier research (Nieveen, 1997, 1999), Table 2 provides an overview of the relationship between the research questions (with on the verical axis the quality criteria concerning the elements of an intervention and on the horizontal axis the development stages, see previous section) and suitable formative evaluation methods (indicated in the cells). Here we distinguish the following methods. Please refer for an extensive overview for instance to Tessmer (1993) or Brinkerhoff, et al. (1983):

- Screening: members of the design research team check the design with some checklists on important characteristics of components of the prototypical intervention.
- Expert appraisal: a group of experts (for instance, subject matter experts, instructional design experts, teachers review the materials) reacts on a prototype of an intervention, usually on the basis of a guideline with central questions of the design research team. Usually this is done by interviewing the respondents.
- Walkthrough: the design researcher and one or a few representatives of the target group together go through the set up of the intervention. Usually this is carried out in a face to face setting.

- Micro-evaluation: a small group of target users (e.g. learners or teachers) uses parts of the intervention outside its normal user setting. Here, the main activities of the evaluator are observing and interviewing the respondents.
- Try-out: a limited number of the user group (e.g. teachers and learners) uses the materials in the day to day user setting. If the evaluation focuses on practicality of the intervention, the following evaluation activities are common: observation, interviewing, requesting logbooks, administering questionnaires; if the evaluation has its focal point on the effectiveness of the intervention, evaluators may decide to request learning reports and/or give a test.

Summative evaluation methods, such as (quasi-)experiments, surveys and accompanying case-studies, follow these formative evaluation activities as soon as the intervention has become fully grown and has been implemented in educational practice (see for instance Rossi, Freeman & Lipsey, 1999).

Design stage / Quality criterion		Design specifications	Global design	Partly detailed intervention	Complete intervention	Implemented intervention
Relevance		- Screening - Expert appraisal	- Screening - Expert appraisal	- Screening - Expert appraisal	- Screening - Expert appraisal	
Consistency		- Screening - Expert appraisal	- Screening - Expert appraisal	- Screening - Expert appraisal	- Screening - Expert appraisal	
Practicality	*expected*	- Screening - Expert appraisal	- Screening - Expert appraisal	- Expert appraisal - Walkthrough	- Expert appraisal - Walkthrough	
	actual			- Micro-evaluation	- Micro-evaluation - Try-out	Survey, (Quasi) experiment, Case-study
Effective-ness	*expected*	- Screening - Focus group	- Screening - Focus group	- Expert appraisal	- Expert appraisal	
	actual			- Micro-evaluation	- Micro-evaluation - Try-out	Survey, (Quasi) experiment, Case-study

Table 2: Table for selecting formative evaluation methods

When interventions become more detailed, the focus of the formative evaluation will gradually shift with respect to the aforementioned quality criteria. In an early stage, the main focus will be on the relevancy and consistency of a prototype. As soon as a global intervention has been designed, design researchers also would like to assess the expected practicality of the intervention. When the intervention is even more elaborated, then the focus will shift towards the actual practicality and effectiveness. In table 2, it is indicated in grey that with this shift in focus also other, more suitable, evaluation methods will come into play. Moreover, each development stage may consist of several cycles of analysis, design and formative evaluation before the prototype will grow into a next development stage.

Sampling - selecting respondents

To be able to answer the research questions with the chosen evaluation methods, the required type and number of respondents need to be discussed. The type and sample size depend on the research questions. With respect to the type of respondents, one needs to select those respondents that can help answering the research questions. For instance, in case design researchers want to gain insight in the relevancy of the design from a subject matter perspective they will select a number of experts in that specific domain to do an expert appraisal. In case insights are needed in the actual practicality of a learning package for learners by performing a micro-evaluation, students need to be sampled who will have to work with the intervention. Moreover, the main purpose of the evaluation also influences the sample *size*. In case of a formative evaluation during early stages of the project, the main purpose is to locate shortcomings in the intervention and to generate suggestions for *improvement* (see also definition of formative evaluation), the number of respondents is less critical: a remark of only one respondent could be highly valuable because of its salience. Small samples of respondents are usually sufficient if they are carefully selected. Samples are usually deliberately chosen (also referred to as purposive sampling where subjects are selected because of some characteristic), in such a way that the comments and reactions will be as information-rich as possible. This means that for instance for organizing a micro-evaluation in order to gain insights into the practicality of a prototype of some learner materials, next to high-achieving students also a group of low-achieving and a group of avarage students need to be selected. Triangulation is important here in order to enhance the reliability and internal validity of the findings (cf. Miles & Huberman, 1994). One could triangulate by using different type of persons, different times, different places. The effectiveness of triangulation rests on the premise that the weaknesses in each single data source will be compensated by the counterbalancing strength of another. In case of a summative evaluation, when the main purpose of an evaluation is *to proof* the actual practicality and effectiveness, (quasi-)experimental research designs with experimental and control settings are required with large sample sizes. For more information on sampling see for instance Creswell (2008), Denscomb (2007) and Mills, Gay, Airasian and Airasian (2008).

When inviting respondents for a formative evaluation it is necessary to illuminate their role. They could fulfill the role of learner, critic and/or revisor (Weston, McAlpine & Bordonaro, 1995). Respondents with a *learner* role are not specifically expert in the subject matter which is covered by the materials. One could think of students who learn a new subject; but also teachers who have not taught in a certain manner before. In many cases experts represent this category as well. For instance, educational technology experts do not always have expertise in the subject matter domain of the educational intervention. They will take the role of a learner first, before they will give comments on matters related to educational technology (in which they are experts). *Critics* are respondents who are asked to comment on the materials from the perspective of their expertise. This group consists, for instance, of subject matter experts and teachers who are invited to make statements about the difficulty or readability of learner materials. *Revisors* will not only give comments on the materials (like critics do), but they will also provide suggestions for improvements. For instance, a subject matter expert may indicate what type of 'state-of-the-art knowledge' is missing in the learner materials and where this knowledge could be found. It is important to note that individuals may play several roles simultaneously during the formative evaluation. The next section will elaborate on the role of the researchers during a formative evaluation.

Researchers' role during formative evaluation

Since a design research project comes into play when a need arises to solve a complex educational problem for which no ready-made solutions are available, oftentimes a multi-disciplined team is brought together to work on it. Such teams usually comprise of experts in domains that were distinguished when decomposing the intervention (e.g. from a conceptual point of view: subject matter experts, pedagogical experts, instructional designers; from a presentation-mode point of view: user-interface designers) as well as members of the target group. Monk, Wright, Haber and Davenport (1993, p. 5) stress that "It requires access to people typical of those who will actually use the system, not their representatives or management." Involving future users in a design research team has several advantages (cf. Moonen, 1996; Shneiderman, 1992): more accurate information about complexity of the problem at hand, more intensive discussions about the requirements of the intervention, increase of user commitment and ownership of the final deliverable, increase of insights into the requirements of the context in which the intervention will be used, and stimulation of the professional development of all participants.

One of the key responsibilities of the design research team is to work on the formative evaluation of the prototypes. For reasons of scientific rigor, it is often recommended to look for external evaluators. However, certainly in the early stages of a design research project it seems legitimate or even advisable that design researchers *themselves* carry out the formative evaluation of the prototype. Engaging in formative evaluation activities tend to lead to important learning experiences of the design researchers. They will experience themselves the problems that occur and hear out of first hand the suggestions for improvement that respondents come up with during their use of a prototype (for example, by observing or interviewing teachers or students). This usually has stronger and more

direct impact on their thinking and design activities, compared to cases where external evaluators report the results to the developers.
Of course, design researchers need to be aware of several pitfalls when they are involved in the formative evaluation of the intervention they are also designing (cf. McKenney, Nieveen & van den Akker, 2006). They may easily become too 'attached' to their prototype which could lead to a less objective view toward problems and comments from the respondents. In this respect, Scriven (1991) warns of a (co-)authorship bias. Moreover, respondents could be biased during the evaluation, as well. For instance, if they know how much effort the design research team has put into the prototype, they may hesitate to be fully critical of it. To overcome these biases, it seems essential to include formative evaluation early on in the development process and to apply triangulation of data sources, methods (observation, interview, questionnaires, etc.), evaluators (different evaluators) and theories (different conceptual frameworks).

Closing remark

This chapter focuses on the iterative nature of educational design research. Each iteration or cycle of analysis, design and formative evaluation gives the design research team firmer ground and arguments for the intervention the team is working on in order to solve a complex educational problem. The empirical data the team collects during a formative evaluation will not only provide suggestions for improving the intervention, but will also assist in sharpening the accompanying design principles. Proceeding through several of these iterations will end in a final stage of the scientific cycle in which claims of causality can be studied in summative evaluation settings (cf. Nieveen, McKenney & van den Akker, 2006).
In this contribution we concentrated on the research design for each formative evaluation performed within such an iterative or prototyping approach. We elaborated on the research questions, selection of appropriate methods and respondents. We are aware that there is much more to say about formative evaluation in general, and integrated in design research projects in particular. For instance, we could have paid attention to evaluation instruments, data collection, data analysis and reporting. Several helpful books and articles are available to assist in systematically conducting formative evaluation in education (cf. Brinkerhoff, et al., 1983; Flagg, 1990; Tessmer, 1993). Although these sources were not written with the specific needs and wishes of design researchers in mind, they can provide ample inspiration.

References

Brinkerhoff, R.O., Brethouwer, D.M., Hluchyj, T., & Nowakowski, J.R. (1983). *Program evaluation: A practitioner's guide for trainers and eduacators.* Boston: Kluwer-Nijhoff.

Creswell, J.W. (2008). *Educational research: planning, conducting and evaluating quantitative and qualitative research.* Upper Saddle River, NJ: Pearson.

Denscomb, M. (2007). *The good research guide for small-scale social research projects*. Maidenhead (UK): Open University Press.

Design-based research collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Flagg, B.N. (1990). *Formative evaluation for educational technologies*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Joint Committee on Standards for Educational Evaluation (1994). *The program evaluation standards.* Thousand Oaks, CA: Sage Publications.

Lincoln, Y. & Guba, E.G. (1979). The distinction between merit and worth in evaluation. *Paper presented at the Annual Meeting of the Evaluation Network* (5th, Cincinnati, OH, September 24-26, 1979) retrieved October 20, 2008, http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/32/b5/c8.pdf

Linn, M., Davis, E.A., & Bell, P. (2004). *Internet environments for science education*. Hillsdale: Lawrence Erlbaum.

McKenney, S. Nieveen, N. & Akker, J. van den (2006). Design research from a curriculum perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 67-90). London: Routledge.

Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis: An expanded source book*. London: Sage.

Mills, G., Gay, L.R., Airasian,P. & Airasian, P.W. (2008). *Educational research: competencies for analysis and applications.* Upper Saddle River, NJ: Prentice Hall.

Monk, A., Wright, P., Haber, J., & Davenport, L. (1993). *Improving your human-computerinterface: A practical technique.* New York: Prentice Hall.

Moonen, J. (1996). Prototyping as a design method. In Tj. Plomp, & D.P. Ely (Eds.), *International encyclopedia of educational technology* (pp. 186-190). Oxford: Pergamon.

Nieveen, N.M. (1997). *Computer support for curriculum developers: A study on the potential of computer support in the domain of formative curriculum development,* Doctoral dissertation. Enschede: University of Twente.

Nieveen, N. (1999). Prototyping to reach product quality. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen, and T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 125–36). Dordrecht: Kluwer Academic Publishers.

Nieveen, N.M., & Akker, J.J.H. van den (1999). Exploring the potential of a computer tool for instructional developers. *Educational technology research & development, 47*(3), 77-98.

Nieveen, N., McKenney, S., & Akker, J. van den (2006). Educational design research: The value of variety. In J. van den Akker, K. Gravemeijer, S. McKenney, and N. Nieveen (Eds.), *Educational design research* (pp. 151-158). London: Routledge.

Reeves, T. (2000). Enhancing the worth of instructional technology research through "design experiments" and other developmental strategies. Retrieved Oct. 20, 2006 from http://it.coe.uga.edu/~treeves/AERA2000Reeves.pdf

Rossi, P.H., Freeman, H.E. & Lipsey, M.W. (1999). *Evaluation: A systematic approach*. Thousand Oaks, CA: Sage.

Scriven, M. (1967). The methodology of evaluation. In R.W. Tyler, R.M. Gagné, & M. Scriven (Eds.), *Perspectives of curriculum evaluation*. AERA Monograph series on curriculum evaluation. nr.1. Chicago, MI: Rand McNally.

Scriven, M. (1991). Beyond formative and summative evaluation. In M.W. McLaughlin, & D.C. Phillips (Eds.), *Evaluation and education: At quarter century* (pp. 19-64). Chicago: University of Chicago.

Shneiderman, B. (1992). *Designing the user interface: Strategies for effective human-computer interaction*. Reading, MA: Addison-Wesley.

Smith, M.F. (1991). *Software prototyping: Adoption, practice and management.* London: McGraw-Hill.

Tessmer, M. (1993). *Planning and conducting formative evaluations: Improving the quality of education and training.* London: Kogan Page.

Van den Akker, J. (1999). Principles and methods of development research. In J. van den Akker, R. Branch, K. Gustafson, N. Nieveen, and T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 1–15). Dordrecht: Kluwer Academic Publishers.

Van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1-10). Dordrecht: Kluwer Academic Publishers.

Wademan, M. (2005). *Utilizing development research to guide people capability maturity model adoption considerations.* Unpublished doctoral dissertation. Syracuse: Syracuse University.

Weston, C., McAlpine, L., & Bordonaro, T. (1995). A model for understanding formative evaluation in instructional design. *Educational training research & technology, 43*(3), 29-48.

6. References and Sources on Educational Design Research

Tjeerd Plomp and Nienke Nieveen

Introduction

This bibliography has been compiled to support researchers and graduate students in getting access to key publications on design research. We do not claim that the selection of sources included in this chapter is complete and exhaustive – *it is coloured by our background and bias as well as our knowledge and familiarity with publications*. Important criteria for us to include titles in this bibliography are (i) proven usefulness of sources for our own work, and (ii) representing important perspectives and groups that are (or have been) actively working in this domain.

In the first section we present just an overview of relevant sources available. This is followed by a section in which we present the structure and content of the excellent website 'Design-based Research EPSS' (http://projects.coe.uga.edu/dbr/index.htm)– created by Instructional Technology Ph.D. students at The University of Georgia (last update November 2006). Given the quality and completeness of this website (at least till November 2006), we decided to introduce it in a separate section and in the other sections of this chapter we will refer to parts of this website, but also introduce a number of other sources. In the following two sections we point the reader to selected journal articles and book chapters on the concept and methodology of design research and on design research in domains such as curriculum, instructional technology, and the learning of reading and writing, mathematics and science. In the final section, we list the URLs of a number of doctoral theses that have been defended in The Netherlands utilizing design research as a research approach.
As stated, our selection is coloured by our bias and experience, but all these publications refer to a wide range of writings on design research and we trust that they therefore serve as a useful introduction to the reader.

Overview of sources

This section presents titles and references to various special issues of journals and books that have been published about design(-based) research. Besides a number of websites will be listed.

Special issues of journals

- **Educational Psychologist, 39 (4), 2004**
  Special issue 'Design-based research methods for studying learning in context', edited by W. Sandoval & P. Bell, including:
  - Sandoval, W. A., & Bell, P. L. (2004). Design-Based Research Methods For Studying Learning In Context: Introduction. *Educational Psychologist, 39*(4), 199-201.
  - Hoadley, C. (2004). Methodological alignment in design-based research. *Educational Psychologist, 39*(4), 203-212.
  - Sandoval, W. A. (2004). Developing learning theory by refining conjectures embodied in educational designs. *Educational Psychologist, 39*(4), 213-223.
  - Tabak, I. (2004). Reconstructing Context: Negotiating the Tension between Exogenous and Endogenous Educational Design. *Educational Psychologist, 39*(4), 225-233.
  - Joseph, D. (2004). The Practice of Design-Based Research: Uncovering the Interplay Between Design, Research, and the Real-World Context. *Educational Psychologist, 39*(4), 235-242.
  - Bell, P. L. (2004). On the theoretical breadth of design-based research in education. *Educational Psychologist, 39*(4), 243-253.
  - Also includes commentary by Angela O'Donnell.

- **Educational Researcher 32 (1), January/February 2003**
  Special issue prepared by A.E. Kelly, including:
  - Kelly, A.E. (2003). Theme Issue: The Role of Design in Educational Research. *Educational Researcher, 32*, 3-4.
  - The Design-Based Research Collective Design-Based Research (2003). An Emerging Paradigm for Educational Inquiry. *Educational Researcher, 32*, 5-8.
  - Cobb, P., Confrey, J., diSessa, A., Lehrer, R. & Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher, 32*, 9-13.
  - McCandliss, B.D., Kalchman, M. & Bryant, P. (2003). Design Experiments and Laboratory Approaches to Learning: Steps Toward Collaborative Exchange. *Educational Researcher, 32*, 14-16.
  - Lobato, J. (2003). How Design Experiments Can Inform a Rethinking of Transfer and Vice Versa. *Educational Researcher, 32*, 17-20.
  - Bannan-Ritland, B. (2003). The Role of Design in Research: The Integrative Learning Design Framework *Educational Researcher, 32*, 21-24.
  - Shavelson, R.J., Phillips, D.C., Towne, L., & Feuer, M.J. (2003). On the Science of Education Design Studies. *Educational Researcher, 32*, 25-28.

- Sloane, F.C & Gorard, S. (2003). Exploring Modeling Aspects of Design Experiments. *Educational Researcher, 32*, 29-31.
- Zaritsky, R., Kelly, A.E., Flowers, W., Rogers, E., & O'Neill, P. (2003). Clinical Design Sciences: A View From Sister Design Efforts. *Educational Researcher, 32*, 32-34.

- **Educational Technology, 45(1), 2005**
  Special issue prepared by C. Dede, including:
  - Dede, C. (2005). Why design-based research is both important and difficult. *Educational Technology, 45*(1), 5-8.
  - Squire, K.D. (2005). Resuscitating research in educational technology: Using game-based learning research as a lens for looking at design-based research. *Educational Technology, 45*(1), 8-14.
  - Barab, S.A., Arici, A., & Jackson, C. (2005). Eat your vegetables and do your homework: A design-based investigation of enjoyment and meaning in learning. *Educational Technology, 45*(1), 15–21.
  - Nelson, B., Ketelhut, D.J., Clarke, J., Bowman, C., & Dede, C. (2005). Design-based research strategies for developing a scientific inquiry curriculum in a multiuser virtual environment. *Educational Technology, 45*(1), 21–28.
  - Kafai, Y.B. (2005). The classroom as "living laboratory": Design-based research for understanding, comparing, and evaluating learning science through design. *Educational Technology, 45*(1), 28–34.
  - Hay, K. E., Kim, B., & Roy, T. C. (2005). Design-based research: More than formative assessment? An account of the Virtual Solar System Project. *Educational Technology, 45*(1), 34-41.
  - Hoadley, C. (2005). Design-based research methods and theory building: A case study of research with SpeakEasy. *Educational Technology, 45*(1), 42-47.
  - Reeves, T. C. (2005). Design-based research in educational technology: Progress made, challenges remain. *Educational Technology, 45*(1), 48-52

- **Journal of the Learning Sciences, 13(1), 2004**
  Special issue, including:
  - Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences, 13*(1), 1-14.
  - Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. *Journal of the Learning Sciences, 13*(1), 15-42.
  - Fishman, B., Marx, R.W., Blumenfeld, P., Krajcik, J., & Soloway, E. (2004). Creating a Framework for Research on Systemic Technology Innovations. *Journal of the Learning Sciences, 13*(1), 43-76.

- diSessa, A.A., & Cobb, P. (2004). Ontological Innovation and the Role of Theory in Design Experiments. *Journal of the Learning Sciences, 13*(1), 77-103
- Dede, C. (2004). If Design-Based Research is the Answer, What is the Question? A Commentary on Collins, Joseph, and Bielaczyc; diSessa and Cobb; and Fishman, Marx, Blumenthal, Krajcik, and Soloway in the JLS Special Issue on Design-Based Research. *Journal of the Learning Sciences, 13*(1), 105-114.
- Kelly, A. (2004). Design Research in Education: Yes, but is it Methodological? *Journal of the Learning Sciences, 13*(1), 115-128.

Books

- Van den Akker, J., Gravemeijer, K, McKenney, S. & Nieveen, N. (Eds). (2006). *Educational design research.* London: Routledge. ISBN10: 0-415-39635-2 (pbk) (163 pages)
  Available at http://www.taylorandfrancis.co.uk/shopping_cart/products/product_detail.asp?sku=&ppid=118302&isbn=9780415396356
  This book comprises the papers presented at a seminar organized by the Netherlands Organization for Scientific Research, in particular by the Program Council for Educational Research. The seminar, conducted in December 2003, has been a meeting place of design researchers from the USA and The Netherlands. The book reflects the various angles from which researchers in the domains of curriculum, instructional technology and (mathematics and science) education address the need to develop research based solutions (interventions) to problems for which no guidelines to solutions are available. The book illustrates that authors with various backgrounds have clearly a common ground when reflecting on design research as a research approach.
  The book has four parts:
  Part 1. What and why
  1. Introducing Educational Design Research - Jan van den Akker, Koeno Gravemeijer, Susan McKenney, Nienke Nieveen
  2. Toward Productive Design Studies - Decker Walker

  Part 2. Examples from the field
  3. Design research from the Learning Design Perspective - Koeno Gravemeijer, Paul Cobb
  4. Design Research from the Technology Perspective - Thomas Reeves
  5. Design Research from a Curriculum Perspective - Susan McKenney, Nienke Nieveen, Jan van den Akker

Part 3. Quality

6. Assessing the Quality of Design Research Proposals: Some Philosophical Perspectives - D.C. Phillips
7. Balancing Innovation and Risk: Assessing Design Research Proposals - Daniel C. Edelson
8. Quality Criteria for Design Research: Evidence and Commitments - Anthony E. Kelly

Part 4. Moving ahead

9. From Design Research to Large-Scale Impact: Engineering Research in Education - Hugh Burkhardt
10. Educational Design Research: The Value of Variety - Nienke Nieveen, Susan McKenny, Jan van den Akker

- Kelly, A.E., Lesh, R.A. & Baek, J.Y. (Eds). (2008). *Handbook of Design Research Methods in Education Innovations in Science, Technology, Engineering, and Mathematics Learning and Teaching*. New York: Lawrence Erlbaum Associates. ISBN: 978-0-8058-6059-7 (pbk) (560 pages)
  Available at http://www.routledgeeducation.com/books/Handbook-of-Design-Research-Methods-in-Education-isbn9780805860597
  The announcement of the book states that the handbook presents the latest thinking and current examples of design research in education. Design-based research involves introducing innovations into real-world practices (as opposed to constrained laboratory contexts) and examining the impact of those designs on the learning process. Designed prototype applications (e.g., instructional methods, software or materials) and the research findings are then cycled back into the next iteration of the design innovation in order to build evidence of the particular theories being researched, and to positively impact practice and the diffusion of the innovation.
  The *Handbook of Design Research Methods in Education* is meant to fill a need in how to conduct design research by those doing so right now. The chapters represent a broad array of interpretations and examples of how today's design researchers conceptualize this emergent methodology across areas as diverse as educational leadership, diffusion of innovations, complexity theory, and curriculum research.
  The handbook has eight sections:
  - Design research and its argumentative grammar
  - Modeling student learning during design research
  - Modeling teacher learning using design research
  - Modeling stakeholders commitments using design research
  - Reflecting on design research at the project level

- Reflecting on design research at the program level
- Extending design research methodologically
- Tracking the diffusion of design research.

- Reinking, D. & Bradley, B.A. (2008). *On Formative and Design Experiments: Approaches to Language and Literacy Research.* New York & London: Teachers College, Columbia University. ISBN: 978-0-8077-4841-1 (pbk) (134 pages)
  This booklet provides a nice introduction into formative and design experiments, a term synonymous for what we call design research and others design-based research. It provides a thorough, but practical and useful overview of design research addressing the following questions:
  - What are formative and design experiments (Ch1)?
  - What are the methods of formative and design experiments (Ch2)?
  - What are some good examples of formative and design experiments (Ch3)?
  - Is there a formative or design experiment in your future (Ch4)?

- Richey, R. & Klein, J.D. (2007). *Design and development research: methods, strategies, and issues.* London: Routledge. ISBN 080585732X, 9780805857320 (180 pages)
  This volume discusses methods and strategies appropriate for conducting design and development research. Rich with examples and explanations, the book describes actual strategies that researchers have used to conduct two major types of design and development research: 1) product and tool research and 2) model research. Common challenges confronted by researchers in the field when planning and conducting a study are explored and procedural explanations are supported by a wide variety of examples taken from current literature.

Websites

- http://projects.coe.uga.edu/dbr/index.htm (last update November 2006):
  titled 'Design-based Research EPSS'– created by Instructional Technology Ph.D. students at The University of Georgia under supervision of Tom Reeves (comprehensive till last update of November 2006). This website is summarized in the next section.

- http://cider.athabascau.ca/CIDERSIGs/DesignBasedSIG/dbrreferences (last update early 2005):
  This bibliography is drawn up by Terry Anderson of the Univesity of Athabasca (Edmonton, Alberta, Canada). Anderson calls it a snapshot of most current (early 2005) literature related to discussion, exploration and examples of design-based research. The references are presented with URLs (if available) along with abstracts and occasionally quotations or annotations by Anderson. Has much overlap with the University of Georgia website.

- http://www.designbasedresearch.org/index.html (last update not clear, but no references later than 2004)

This is the website of the Design-Based Research Collective, a small group of researchers who engage in design-based research, often in technology enhanced learning environments. It contains references of a number of publications, as well as a number of links to relevant related websites.

Other publications

Apart from the sources mentioned above, many articles and book chapters have been published dealing with conceptual and/or methodological aspects of design research, or reporting about design research projects. Many of these references (plus abstracts) can be found on the websites mentioned in this section, but we have selected a number which are summarized in the final section of this chapter.

UGA Website 'Design-based Research EPSS', November 2006

The URL of the UGA website Electronic Performance Support System (EPSS) is: http://projects.coe.uga.edu/dbr/index.htm.

The website (November 2006), created by *Instructional Technology Ph.D. students at The University of Georgia* (UGA), supervised by Tom Reeves[1], has three parts:

1. PEER Tutorial
2. Webliography
3. Expert Interviews

1. PEER Tutorial

This useful tutorial is composed of four primary sections:

(i) tutorial survey,

(ii) explanation,

(iii) enactment, and (iv) reflection.

Parts (ii) and (iii) are useful and informative to become familiar with design research and how to get started.

(ii) Explanation:

The purpose of the explanation part of the tutorial is to provide the user with fundamental knowledge and insight about design research composed of five sections:

- What is Design-based Research (DBR)?
- How does DBR differ from other approaches?
- How did DBR get started?
- What are the benefits of DBR?

[1] The authors of this website use the term Design Based Research (DBR), whilst we use throughout this booklet the term 'Design Research': both terms should be seen as synonymous.

- What are some critical perspective?

Each section is concise and provides core information with ample references to literature.
(iii) Enactment:
This part consists of three sections:
- How do I get started with Design-Based Research (DBR)?
- Some examples of DBR
- What are the challenges of doing DBR?

Each section discusses a number of relevant topics for those who want to conduct Design Research (DR) or Design-Based Research.
As stated, this is a useful tutorial. But keep in mind that authors may differ in emphasis, approach and/or use of terms and concepts. But when you are an open-minded, critical reader you will find many useful ideas and suggestions in this tutorial.

2. Webliography

The purpose of this part of the website is – according to its creators – to provide various types of resources that may provide interested researchers a beginning point for investigating and pursuing the topic of design-based research.
Warning: As the website has been prepared in 2006, it may be possible that some of the URLs referred to are no longer accessible or active.
The webliography has the following sections:
(i) Glossary
A limited number of key concepts are defined, the most important being design-based research.
(ii) Printed resources
One book is listed (Van den Akker, et al., 2006) and quite a number of journal articles (and their abstracts), divided into methodological articles and research examples. This is a useful list of publications up 'till November 2006, and especially those published in North America.
(iii) Online resources
This section has a number of sub-sections: a number of useful websites, two online journals (too limited to be really useful), and the URLs of a number of useful articles.
(iv) Organizations
Two organizations are mentioned, viz. Design-based Research Collective (DBRC) and the Design-based Research SIG of the Canadian Institute of Distance Education Research, but the websites of both organizations seem not to be up to date. Nevertheless, the website of DBRC (http://www.designbasedresearch.org/index.html) gives useful references to two special issues of journals:

- Kelly, E.A. (Ed.). (2003). The role of design in educational research [special issue]. *Educational Researcher, 32 (1).*
- Sandoval, W. & Bell, P. (Eds.). (2004). Design-based research methods for studying learning in context [Special Issue]. *Educational Psychologist, 39* (4)[2].

(v) Experts in design-based research
Contains short biographical notes and a picture of a number of experts in design research (amongst them all except the first author of this booklet).
(vi) Frequently Asked Questions (FAQ):
Three questions are addressed, viz what is design-based research (DBR), how to begin with DBR, and how does DBR differ from other research methodologies.

3. Expert interviews

This part of the website contains a number of videotaped interviews with a number of experts in design research.

Selected journal articles and book chapters on concept and methodology

There are so many publications on educational design research that it is impossible to draw up a comprehensive bibliography. A number of publications have already been listed (with abstracts) on the UGA website (see 6.2).
However we want to point the reader to a number of articles and chapter that have helped us to get involved in design research and to understand the main issues in our field. Given this rationale for selecting these titles, the reader will find that some of the titles are also referred to on the UGA website.

Akker, J. van den (1999). Principles and methods of development research[3]. In J. van den Akker et al. (Eds.), *Design approaches and tools in education and training* (pp. 1-14). Dordrecht: Kluwer Academic Publishers.

Abstract: This chapter discusses the role of research in relation to educational design and development activities. The first part of the chapter focuses on the rationale and basic principles of development research by outlining motives for conducting formative research, analyzing definitions and aims of various types of development research, and discussing several of its key characteristics. The second part of the chapter deals with

[2] The website of this special issue offers the opportunity to purchase articles for € 22.00 plus VAT.
[3] The concept development research, used in some titles, is synonymous to design research.

methods of development research, exploring some of its typical problems and dilemmas, and discussing several challenges for further action and reflection.

Akker, J. van den & Plomp, Tj. (1993). Development research in curriculum: propositions and experiences. Paper presented at the annual conference of the American Educational Research Association, April 1993, Atlanta (GA, USA).

Abstract: Reason to include this paper is that it is the first paper from the group at the University of Twente on what they called at that time development research. Based on the assertion that both curriculum development and curriculum research have much relevance to gain from a close liaison, the authors suggest that boundaries between the two should fade, which can be done in a new research strategy called development research. The paper presents the purpose, a conceptual framework and some characteristics of development research in curriculum
See: www.leerplanevaluatie.slo.nl/taakhulp/lezen

Bannan-Ritland, B. (2003). The role of design in research: The integrative learning design framework. *Educational Researcher, 32* (1), 21-24.

Abstract (from UGA website): In this article, a general model is proposed for design research in education that grows out of the author's research and work in related design fields. The model emphasizes the stage sensitivity of (a) research questions, (b) data and methods, and (c) the need for researchers to design artifacts, processes, and analyses at earlier stages in their research that can then be profitably used (perhaps by different researchers) in later stages.

Barab, S. A., and Squire, K. D. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences, 13* (1), 1-14.

Abstract (from UGA website): The article highlights and problematizes some challenges that are faced in carrying out design-based research. It states that the emerging field of learning sciences is one that is interdisciplinary, drawing on multiple theoretical perspectives and research paradigms so as to build understandings of the nature and conditions of learning, cognition and development. A fundamental assumption of many learning scientists is that cognition is not a thing located within the individual thinker but is a process that is distributed across the knower, the environment in which knowing occurs and the activity in which the learner participates. In other words, learning, cognition, knowing and context are irreducibly co-constituted and cannot be treated as isolated entities or processes.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*, 141-178.

Abstract (from UGA website): This is the seminal article on design research. Discusses theoretical and methodological challenges in creating complex interventions in classroom settings. Movement from the classical psychological position of concentrating on a theoretical study of the learning processes of individual students to a concentration on conceptual change in teachers and students; Classroom restructuring; Design experiments; Experiences on learning theory.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32* (1), 5-8.

Abstract (from UGA website): The authors argue that design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice. Design based researchers' innovations embody specific theoretical claims about teaching and learning, and help us understand the relationships among educational theory, designed artifact, and practice. Design is central in efforts to foster learning, create usable knowledge, and advance theories of learning and teaching in complex settings. Design based research also may contribute to the growth of human capacity for subsequent educational reform.

Kelly, A. E. (2006). Quality criteria for design research. In: J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.). *Educational design Research.* London: Routledge.

Abstract: this chapter discusses for each of three different uses for design research in education a number of characteristics and exemplary examples. It introduces the notion of the commissive space of design research, meaning that (amongst other characteristics) design research does not strive for context-free claims but sees contexts as central to its conceptual domain, that design research is experimental but not an experiment, and that design researchers choose to work in the "context of discovery", rather than in the "context of verification" utilizing randomized trials.

Reeves, T. (2000). Enhancing the worth of instructional technology research through "design experiments" and other developmental strategies Paper presented at the Annual Meeting of the American Educational Research Association, April 2000, New Orleans (LA, USA).
Retrieved Oct. 20, 2006 from http://it.coe.uga.edu/~treeves/AERA2000Reeves.pdf

Abstract: The author argues that in general research in the area of instructional technology is poor, not providing practitioners with sufficient guidance. He discusses various types of instructional technology research goals and methods and suggests that 'use-inspired basic research' is needed in the domain of instructional technology referring to approaches like development research and design experiments. He presents a framework and characteristics for development research in the area of instructional technology.

Selected journal articles and book chapters on design research in domains

Over the last few years, increasingly examples of design research have been published. This section contains just a few exemplary references to articles and chapters in books of design research in various domains, of which a few are taken from the UGA website
We have added in the next section references to some PhD dissertations reporting on design research conducted at Dutch universities that can easily be accessed through the World Wide Web.

Domain of mathematics education

A seminal chapter is:

Gravemeijer, K. & Cobb, P. (2006). Design research from the learning design perpective, in van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.) Educational Design research: The design, development and evaluation of programs, processes and products. London: Routledge, 17-51.

Abstract: this chapter presents an approach to design research that has been used and refined in a series of design research projects in which the two authors collaborated over a ten-year period. Their approach is falling within the broader category of design research that aims at creating innovative learning ecologies in order to develop local instruction theories on the one hand, and to study the forms of learning that those learning ecologies are intended to support on the other hand in the domain of mathematics education (including statistics education).
The approach to design research has its roots in the history of the two authors which is the work on realistic mathematics education (RME) that is carried out in the Netherlands (first author) and that of socio-constructivist analysis of instruction (second author).

Some references[4] for design research cases in the domain of mathematics education conducted in the USA are:

4) We want to express our thanks to Paul Cobb for providing these references.

Bowers, J. S., Cobb, P., & McClain, K. (1999). The evolution of mathematical practices: A case study. *Cognition and Instruction, 17*, 25-64.
Cobb, P. (1999). Individual and collective mathematical learning: The case of statistical data analysis. *Mathematical Thinking and Learning, 1,* 5-44.
Cobb, P., McClain, K., & Gravemeijer, K. (2003). Learning about statistical covariation. *Cognition and Instruction, 21,* 1-78.
Confrey, J., & Smith, E. (1995). Splitting, covariation, and their role in the development of exponential functions. *Journal for Research in Mathematics Education, 26*, 66-86.
Lehrer, R., & Schauble, L. (2004). Modeling natural variation through distribution. *American Educational Research Journal, 41*, 635-679.
Lobato, J. (2003). How design experiments can inform a rethinking of transfer and vice versa. *Educational Researcher, 32*(1), 17-20.
Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education, 26*, 114-145.
Stephan, M., Bowers, J., & Cobb, P. (Eds.). (2003). *Supporting students' development of measuring conceptions: Analyzing students' learning in social context. Journal for Research in Mathematics Education Monograph No. 12.* Reston, VA: National Council of Teachers of Mathematics.

An illustrative example of design research in the context of a developing country is:
Vos, P., Devesse, T.G., and Pinto, A.A.R. (2007). Designing Mathematics Lessons In Mozambique: Starting From Authentic Resources. *African Journal of Research in SMT Education, 11*(2), pp. 51-66

Abstract: This article describes research on the design of student-centred instruction in Mozambique. The starting point was the use of real-life resources, such as traditional art craft objects and authentic newspaper clippings. The research was based on an instructional design model, which attempts to align theory with practice and which is geared towards improving practice. In two parallel studies, one on geometry and one on statistics, student-centred instruction was facilitated through the use of worksheets with open-ended questions tailored for group work. In a cyclic process, the prototype materials and the associated instructional method were formatively evaluated. The evaluations showed that the designs were useful even in classrooms packed with more than sixty students.

Domain of science education

Hoadley, C. M., & Linn, M. C. (2000) Teaching science through online, peer discussions: SpeakEasy in the knowledge integration environment. *International Journal of Science Education*, 22 (8), 839-857.

Abstract: This article discusses whether students can learn science from carefully designed online peer discussions. Contrasts two formats of contributed comments--historical debate and narrative text--and assesses the impact of an asynchronous discussion on student understanding of the nature of light. It also reports that students gain integrated understanding of the nature of color from both discussion formats.

Kafai, Y. B., & Ching, C. C. (2001). Affordances of collaborative software design planning for elementary students' science talk. *Journal of the Learning Sciences,* 10 (3), 323-363.

Abstract: This article investigates whether science permeates the design environment and is thus contexted within the other activities of collaborative management and technology. Focuses on which contexts gave rise to science talk. Studies a classroom with (n=33) students divided into seven teams

Knippels, M.C.P.J., Waarlo, A.J., and Boersma, K.Th. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education*, 39(3), 108-112.

Abstract: While learning and teaching difficulties in genetics have been abundantly explored and described, there has been less focus on the development and field-testing of strategies to address them. To inform the design of such a strategy a review study, focus group interviews with teachers, a case study of a traditional series of genetics lessons, student interviews, and content analysis of school genetics teaching were carried out. Specific difficulties reported in the literature were comparable to those perceived by Dutch teachers and found in the case study and the student interviews.The problems associated with the abstract and complex nature of genetics were studied in more detail. The separation of inheritance, reproduction and meiosis in the curriculum accounts for the abstract nature of genetics, while the different levels of biological organisation contribute to its complex nature. Finally, four design criteria are defined for a learning and teaching strategy to address these problems: linking the levels of organism, cell and molecule; explicitly connecting meiosis and inheritance; distinguishing the somatic and germ cell line in the context of the life cycle; and an active exploration of the relations between the levels of organisation by the students.
Key words: Biology education; Genetics; Learning and teaching difficulties; Design criteria

Lijnse, P.L. (1995). "Developmental Research" as a way to an empirically based "Didactical Structure" of Science. *Science Education, 29* (2), 189-199.

Abstract: The author argues that developmental research (in this book called *´design research'*) is needed in which small-scale curriculum development is cyclically coupled to in-depth classroom research of teaching-learning processes. Such research should result in worked out examples of successful ways of teaching, according to new

conceptual curriculum structures. Designing such `didactical´ structures constitutes a longer term research program, which asks for international exchange and cooperatition.

Domain of reading - writing

Abbott, S. P., Reed, E., Abbott, R. D., & Berninger, V. W. (1997). Year-long balanced reading/ writing tutorial: A design experiment used for dynamic assessment. *Learning Disability Quarterly,* 20(3), 249-263.

Abstract: Sixteen children with severe reading problems in first grade received a year-long individual tutorial intervention. Growth curve analyses found significant gains on measures of orthographic and phonological coding, word identification, word attack skills, reading comprehension, letter automaticity, and spelling and marginally significant gains in writing composition.

DeCorte, E., Verschaffel, L., & van de Ven, A. (2001). Improving text comprehension strategies in upper primary school children: A designexperiment. *The British Journal of Educational Psychology,* 71, 531-559.

Abstract: With respect to the acquisition of competence in reading, new standards for primary education stress more than before the importance of learning and teaching cognitive and metacognitive strategies that facilitate text comprehension. Therefore, there is a need to design a research-based instructional approach to strategic reading comprehension. The design experiment aimed at developing, implementing and evaluating a research-based, but also practically applicable learning environment for enhancing skilled strategy use in upper primary school children when reading a text. This design experiment shows that it is possible to foster pupils' use and transfer of strategic reading comprehension skills in regular classrooms by immersing them in a powerful learning environment. But this intervention does not automatically result in improvement of performance on a standardized reading comprehension test.

Neuman, S. B. (1999). Books make a difference: A study of access to literacy. *Reading Research Quarterly,* 34 (3), 286-311.

Abstract: This article examines the impact of an intervention targeting economically disadvantaged children that flooded over 330 child-care centers with high-quality children's *books* and provided 10 hours of training to child-care staff. It examines the project's impact and gives support for the physical proximity of *books* and the psychological support to child-care staff on children's early-literacy development.

Domain of instructional technology

Bannan-Ritland, B. (2003). The role of design in research: The integrative learning design framework. *Educational Researcher,* 32(1), 21-24.

Abstract: (from UGA website): In this article, a general model is proposed for design research in education that grows out of the author's research and work in related design fields. The model emphasizes the stage sensitivity of (a) research questions, (b) data and methods, and (c) the need for researchers to design artifacts, processes, and analyses at earlier stages in their research that can then be profitably used (perhaps by different researchers) in later stages.

Herrington, J., & Oliver, R. (1997). Multimedia, magic and the way students respond to a situated learning environment. *Australian Journal of Educational Technology*, 13(2), 127-143. Available at: http://www.ascilite.org.au/ajet/ajet13/herrington.html

Abstract: This article presents a design of an interactive multimedia learning environment entitled Investigating assessment strategies in mathematics classrooms, which represents the operationalized characteristics of situated learning. The authors also suggest the critical guidelines for the design of the multimedia software to enable it to support a situated learning environment. They then report a study that investigates patterns of behavior of students immersed in this multimedia situated learning environment. The findings suggest that the use of the situated learning model is successful in providing guidelines for the development of an interactive multimedia program. They also reveal that in instances where learners are empowered and are enabled to assume higher degrees of responsibility for their activity and conduct in a learning setting, the researchers need to be cognizant of the various design factors which can impede or enhance learning. In multimedia environments, these include such elements as the motivational aspects of the environment, the interface design, and the navigation elements employed. In conclusion, the authors suggest that it is also important to practice research which explores the impact of the more tangible aspects of multimedia design such as those explored in this study.

Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, 48(3), 23-48. Available at: http://edserver2.uow.edu.au/~janh/Assessment/Authentic%20Assessment_files/ETR%26D.pdf

Abstract: The instructional technology community is in the midst of a philosophical shift from a behaviourist to a constructivist framework, a move that may begin to address the growing rift between formal school learning and real-life learning. One theory of learning that has the capacity to promote authentic learning is that of situated learning.

The purpose of this three part study was firstly, to identify critical characteristics of a situated learning environment from the extensive literature base on the subject; secondly, to operationalise the critical characteristics of a situated learning environment by designing a multimedia program which incorporated the identified characteristics;

and thirdly, to investigate students' perceptions of their experiences using an multimedia package based on a situated learning framework.
The learning environment comprised a multimedia program for preservice teachers on assessment in mathematics, together with recommended implementation conditions in the classroom. Eight students were observed and interviewed to explore their perceptions of the situated learning environment. Findings suggest that the use of the situated learning framework appeared to provide effective instructional design guidelines for the design of an environment for the acquisition of advanced knowledge.

Reeves, T. (2006). Design research from a technology perspective. In: J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.). *Educational design Research*. London: Routledge.
Abstract: The effectiveness of the field known as educational technology in fundamentally enhancing teaching and learning has increasingly been called into question, as has the efficacy of educational research in general. Doubts about educational technology research primarily stem from decades of an arguably flawed research agenda that has been both pseudoscientific and socially irresposible. It is proposed that progress in improving teaching and learning through technology may be accomplished using design research as an alternative model of inquiry. Design research protocols require intensive and long-term collaboration involving researchers and practitioners. It integrates the development of solutions to practical problems in learning environments with the identification of reusable design principles. Examples of design research endeavors in educational technology are described here. The chapter ends with a call for the educational technology research community to adopt design research methods more widely.

Reeves, T. C., Herrington, J., & Oliver, R. (2004). A development research agenda for online collaborative learning. *Educational Technology Research and Development, 52*(4), 53-65.
Abstract: Although important, traditional basic-to-applied research methods have provided an insufficient basis for advancing the design and implementation of innovative collaborative learning environments. It is proposed that more progress may be accomplished through development research or design research. Development research protocols require intensive and long-term collaboration among researchers and practitioners. In this article, we propose guidelines for implementing development research models more widely, and conclude with a prescription for an online collaborative learning research agenda for the next five to ten years.

Reinking, D., & Watkins, J. (2000). A formative experiment investigating the use of multimedia book reviews to increase elementary students' independent reading. *Reading Research Quarterly, 35* (3), 384-419.

Abstract: This study investigates how a computer-based instructional intervention (creating multimedia reviews of books) might increase fourth and fifth graders' independent reading. The study finds that the success of the intervention was related to the mediating effects of using technology, changes in the interactions among students and teachers, and students' engagement in relation to their reading ability. It also notes several other factors.

Domain of curriculum

McKenney, S. & van den Akker, J. (2005). Computer-based support for curriculum designers: A case of developmental research. *Educational Technology Research & Development, 53*(2) 41-66.

Abstract: In this article, we explore the potential of the computer to support curriculum materials development within the context of secondary level science and mathematics education in southern Africa. During the four-year course of the study, a computer program was developed named CASCADE-SEA, which stands for Computer Assisted Curriculum Analysis, Design and Evaluation for Science (and mathematics) Education in Africa. By carefully documenting the iterative process of analysis, prototype design, evaluation, and revision, we sought insight into the characteristics of a valid and practical computer-based tool that possesses the potential to affect the performance of its users. The results of this study include the CASCADE-SEA program itself, which assists users in producing better quality materials than they otherwise might, while they also learn from the development process. Further, this research has contributed to the articulation of design principles and related developmental research methods. This article highlights the research and development that took place, and only briefly addresses the tool itself.

McKenney, S., Nieveen, N, & van der Akker, J. (2002). Computer support for curriculum developers: CASCADE. *Educational Technology Research and Development*, 50 (4), 25-35.

Abstract: This article examines research on a *computer*-based tool, CASCADE (*Computer* Assisted Curriculum Analysis, Design and Evaluation), that was developed at the University of Twente (Netherlands) to assist in curriculum development. The article discusses electronic performance *support* systems and the need for increased attention to implementation and impact studies.

Nieveen, N.M. (1999). Prototyping to reach product quality. In: J.J.H. van den Akker, R. Branch, K. Gustafson, N.M. Nieveen, & Tj. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 125-136). Dordrecht: Kluwer.

Abstract: This chapter provides a framework for product quality consisting of the following three criteria: validity, practicality and effectiveness, and provides insight into the applicability of the framework in various domains of educational product development. In order to reach product quality, the prototyping approach is seen and understood as a suitable approach. This chapter discusses three significant characteristics of a prototyping approach: extensive use of prototypes, high degree of iteration and the role of formative evaluation, and the paramount importance of user involvement. The chapter illustrates the way the prototyping approach has been instrumental in developing a computer support system for instructional developers. During the prototyping process, the framework assisted in deciding the focus of each prototype and enhanced the transparency of the entire process.

Nieveen, N.M. & Akker, J.J.H., van den (1999). Exploring the potential of a computer tool for instructional developers. *Educational Technology Research & Development*, 47(3), 77-98.

Abstract: Information and communication technology tools currently permeate almost every professional domain. Those geared toward the field of instructional development have emerged in recent years. This article explores the potential for linking the domains of computer support and instructional development. This article reports on the design and evaluation of CASCADE (Computer Assisted Curriculum Analysis, Design and Evaluation), a computer system that supports instructional developers during formative evaluation efforts. Five prototypes of the system were created and evaluated on the basis of their validity (reflection of state-of-the-art knowledge and internal consistency); practicality (ability to meet the needs, wishes and contextual constraints of the target group); and effectiveness (improved user task performance). The results of this study suggest that the use of CASCADE could: (a) improve the consistency of formative evaluation plans and activities; (b) motivate developers by elevating their confidence in using formative evaluation activities; (c) save time; and (d) help to provide justifications for decisions made.

Some PhD theses utilizing design research as a research approach

Over the years, various PhD these have been written in which design research has been applied as the main research approach. In this section we just mention a few that have been defended in The Netherlands at the University of Twente and the University of Utrecht.
Undoubtly, many more dissertations can be found via search machines on the WWWeb, but we just want to point the reader to a few examples of design research we are familiar with.

Domain of curriculum development

Nieveen, N. (1997). *Computer support for curriculum developers.* Doctoral thesis. Enschede (The Netherlands) University of Twente,.

Available from: http://projects.edte.utwente.nl/cascade/original/
McKenney, S. (2001). *Computer-based support for science education materials developers in Africa: exploring potentials.* Doctoral thesis. Enschede (The Netherlands): University of Twente.
Available from: http://projects.edte.utwente.nl/cascade/seastudy/

Kouwenhoven, W. (2003). *Designing for competence in Mozambique: towards a competence-based curriculum for the Faculty of Education of the Eduardo Mondlane University.* Doctoral thesis. Enschede (The Netherlands): University of Twente.
Available from: http://doc.utwente.nl/41442/1/thesis_Kouwenhoven.pdf
Note: this is an example of design research in which the researcher was not actively involved in all phases of the design process.

Domain of professional development of teachers

Teclai Tecle, Andemariam (2006). *The potential of a professional development scenario for supporting biology teachers in Eritrea*. Doctoral thesis. Enschede (The Netherlands): University of Twente.
Available from: http://purl.org/utwente/55985

Domain of mathematics education

Armanto, Dian (2002). *Teaching multiplication and division realistically in Indonesian primary schools : a prototype of local instructional theory.* Doctoral thesis. Enschede (The Netherlands) University of Twente.
Available from: http://purl.org/utwente/58710

Bakker, A. (2004). *Design research in statistics education : on symbolizing and computer tools.* Doctoral thesis. Utrecht (The Netherlands: University of Utrecht.
Available from: http://igitur-archive.library.uu.nl/dissertations/2004-0513-153943/inhoud.htm

Fauzan, Ahmad (2002). *Applying realistic mathematics education (RME) in teaching geometry in Indonesian primary schools.* Doctoral thesis. Enschede (The Netherlands) University of Twente.
Available from: http://purl.org/utwente/58707

Domain of science education

Knippels, M.C.P.J. (2002). Coping with the abstract and complex nature of genetics in biology education : The yo-yo learning and teaching strategy. Doctoral thesis. Utrecht (The Netherlands: University of Utrecht.
Available from: http://igitur-archive.library.uu.nl/dissertations/2002-0930-094820/inhoud.htm

Mafumiko, Fidelice Simbagungile Mbaruku (2006). *Micro-scale experimentation as a catalyst for improving the chemistry curriculum in Tanzania.* Doctoral thesis. Enschede (The Netherlands) University of Twente.
Available from: http://purl.org/utwente/55448
Ottevanger, W. (2001). Materials development as a catalyst for science curriculum implementation in Namibia. Doctoral thesis. Enschede: University of Twente.

Tilya, Frank Nicodem (2003). *Teacher support for the use of MBL in activity-based physics teaching in Tanzania.* Doctoral thesis. Enschede (The Netherlands) University of Twente.
Available from: http://purl.org/utwente/41462

Westbroek, H. B. (2005). *Characteristics of meaningful chemistry education - The case of water quality.* Doctoral thesis. Utrecht (The Netherlands: University of Utrecht.
Available from: http://igitur-archive.library.uu.nl/dissertations/2005-0922-200121/index.htm

Author biographies

Jan van den Akker

Jan van den Akker is director general of Netherlands Institute for Curriculum Development [SLO]. Besides, he is part-time professor (chair on Curriculum Design) at the University of Twente. In his wide teaching, research, supervision, and consultancy experiences (both in the Netherlands and abroad) he tends to approach curriculum design challenges from a broader educational innovation perspective. Over the years his preference for design research has increased because of its strong combination of practical relevance and knowledge growth. Some books over the last decade (edited with some colleagues) that represent his orientation: *Design Approaches and Tools in Education and Training* (1999), *Curriculum Landscapes and Trends* (2003), and *Educational Design Research* (2006).

Brenda Bannan

Brenda Bannan is an associate professor in the instructional technology program at George Mason University in Fairfax, Virginia, USA. Her research interests primarily involve the integration of design and research processes related to educational technology design and development. She has authored several articles and chapters on design research in the Handbook for Design Research Methods in Education (Eds. Kelly, Lesh & Baek, 2008) as well as the *Educational Researcher*, vol 32, 2003. Dr. Bannan was awarded an NSF CAREER grant award in 2003 to conduct a five-year cycle of design research and was invited as a visiting scholar at Stanford University for the academic year of 2005-2006.

Anthony E. Kelly

Anthony E. Kelly is a professor of educational psychology at George Mason University in Virginia, USA. His research interests extend to research methodology design, and research at the intersection of cognitive neuroscience and education. He currently has two National Science Foundation grants, one on modeling learning in cyberinfrastructure networks in earth sciences (with Brenda Bannan-Ritland), and one on learning in megacities. His NSF grant on design research methods with Richard Lesh, produced the Handbook of Design Research Methods (Kelly, Lesh & Baek, 2008). Kelly edited the special issue on design research, Educational Researcher, vol 32, 2003. He is the editor of the special issue on the US National Mathematics Advisory Panel Report, *Educational Researcher*, forthcoming. He served as a program manager at the National Science Foundation from 1997-2000, and 2006.

Nienke Nieveen (author and editor)

Nienke Nieveen works at the research department of Netherlands Institute for Curriculum Development [SLO]. Her work centers around coordinating and supporting the Institute's design research activities by taking series of concerted actions to assist curriculum developers in interweaving design and formative evaluation activities. In doing so, SLO aims at knowledge growth and proven quality for all of its products, i.e. curriculum frameworks and teaching and learning materials. Her dissertation, in 1997, was based on a four year design research project and, also after this period, she continued working on design research projects at the University of Twente. She has authored several articles and chapters on design research and co-edited the book *Educational design research*.

Tjeerd Plomp (author and editor)
Tjeerd Plomp is emeritus professor of curriculum of the University of Twente in Enschede, The Netherlands. He has been in charge of teaching educational design methodology in the (at that time) Faculty of Educational Science and Technology. He was chair of IEA, the International Association for the Evaluation of Educational Achievement, from 1989 - 1999. In the IEA he served as chair for the 'Computers in Education' study (Comped), the Third International Mathematics and Science Study (TIMSS) and the IEA Second International Technology in Education Study (SITES). His research interests are educational design and design research, international comparative research, and information technology in the curriculum and teacher education. He has been recently involved as advisor in various research projects and programs utilizing design research, both in The Netherlands and internationally.

SLO is the Netherlands institute for curriculum development. We are bridging the contexts of policy, research, and practice. Our expertise focuses on the development of curricular goals and content for various educational levels, from national policy to classroom practices. We closely collaborate with many different stakeholders from policy circles, schools (boards, principals, teachers), research, civic organizations, and the society at large. This allows us to design and validate relevant curriculum frameworks, to elaborate exemplary materials and to evaluate these in school practices. Our products and services support both policy makers and schools and teachers in making substantive curricular decisions and in elaborating these into relevant, inspiring and effective education.

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