Faculty-based projects on digital learning materials in higher education and design-related research methodologies

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Abstract
In universities, paradigms of learning support that are based on interactive digital learning materials or learning objects, will primarily require design-oriented efforts by faculty. A series of such projects on design, realization, use, implementation and evaluation of digital learning materials in a number of domains in natural and engineering sciences was carried out. Within these projects, methodological issues required considerable time. Literature on design-related research in the fields of information systems and education reveals that articulation of design-related research is not trivial. In this article, this literature is compared with actual experience in faculty-based projects on digital learning materials. It is argued that in such faculty-based projects only certain elements of existing design-related research approaches are applicable and that articulation of an alternative design-related research approach is desirable.

Keywords
design; methodology; interdisciplinary projects; post-secondary education; higher education

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1 Introduction

It has been argued that 'scholarship of teaching' in universities implies corresponding research activities by faculty. An important component of research is reporting and publication. This is beneficial in several ways, it enforces reflection, involves peer review, induces constructive critique and contributes to a shared knowledge base (Boyer, 1996; Shulman, 2001). A major part of such scholarship of teaching efforts goes into the design of teaching-learning activities and corresponding materials. More and more, information and communication technology (ICT) plays a role in such activities. Considerable attention for ICT in education has been allocated to digital learning materials or learning objects. In university education, such digital learning materials are likely to be results of faculty-based projects.

Faculty-based projects on education are projects in which faculty or chair holders within university departments are the primary problem-owners and stakeholders. Such projects will in general require deep understanding of discipline-specific subject matter. In a faculty-based project on design and realization of digital learning material, those who do most of the actual design and development work will have a background in the relevant subject matter knowledge domain and have a position within the relevant chair group. Ideally, there will be infrastructural facilities and some additional resources available such as hard- and software and financial resources for traveling, training, additional expertise etcetera. In practice, for initiatives in the area of technology-enhanced learning, faculty will sometimes be successful in acquiring additional funding from a variety of sources. This may introduce other stakeholders (Carter, 2002) into projects as well.

However, in setting realistic research ambitions, one should take into account that the conditions for research that matches the 'scholarship of teaching' ideal, are different from the conditions in educational research or in information systems research. On the one hand, the type and quantity of resources and the expertise available in faculty-based projects are different. On the other hand, the research paradigms of the subject matter experts in faculty-based projects are likely to be different from those in information systems research and/or educational research. In fact, it is quite generally accepted that research paradigms are different in different disciplines (Patton, 2002; Ziman, 2002).

While certain faculty-based projects may be classified as evaluation research or presented as such (see for instance Dyer, Towns, & Weaver, 2007; Westbrook & Braithwaite, 2001), there are also faculty-based projects that can better be characterized as design-oriented. Part of the research literature on ICT in education can be categorized as faculty-based and implicitly design-oriented. Within this category, part of the literature focuses on digital learning materials.

Examples of publications that rely on faculty-based design-oriented efforts are (Anderson & DiCarlo, 2000; Aziz, Esche, & Chassapis, 2007; Barak & Dori, 2005; Barak, Harward, Kocur, & Lerman, 2007; Breakey, Levin, Miller, & Hentges, 2008; Coffey & Koonce, 2008; Costelloe, Sherry, & Magee, 2009; Deek & McHugh, 2003; Ebner & Holzinger, 2007; Gerosa, Fuks, & Lucena, 2003; Gütl & Pivec, 2003; Holzinger, Emberger, Wassertheurer, & Neal, 2008; Holzinger, Kickmeier-Rust, Wassertheurer, & Hessinger, 2009; Jeschke, Richter, Scheel, & Thomsen, 2007; Miller & Upton, 2008; Navarro & Hoek, 2005; Ong & Mannan, 2004; Reyes-Palomares, Sánchez-Jiménez, & Medina, 2009;

Rodríguez-Caso, Sánchez-Jiménez, & Medina, 2002; Sandvoss, Harwood, Korkmaz, Bollinger, Huffman, & Huffman, 2003; Shanklin, Huang, Lee, Ok, Seo, & Flores, 2003; Shin, Yoon, Lee, & Lee, 2002; Siddiqui, Khan, & Akhtar, 2008; Toumoto, Horiguchi, Hirashima, & Takeuchi, 2006; Yen & Li, 2003; Yokaichiya, Galembeck, & Torres, 2004).

Over a period of almost a decade, we carried out a series of projects on design, realization, use, implementation and evaluation of digital learning material. The materials were aimed at courses in domains such as molecular biology, food science, food chemistry, biotechnology, human nutrition and epidemiology (Aegerter-Wilmsen, Coppens, Janssen, Hartog, & Bisseling, 2005; Busstra, 2008; Busstra, Fesken, Hartog, van 't Veer, & Kok, 2008; Busstra, Geelen, Feskens, Hartog, & van 't Veer, 2008; Busstra, Graaf, & Hartog, 2007; Busstra, Hartog, Kersten, & Műller, 2007; Busstra, Hartog, & van 't Veer, 2005; Corsi, Boyson, Verbraeck, van Houten, Han, & MacDonald, 2006; Diederen, Gruppen, Hartog, Moerland, & Voragen, 2003; Diederen, Gruppen, Hartog, & Voragen, 2005a, 2005b, 2006; Diederen, Gruppen, Voragen, Hartog, Mulder, & Biemans, 2002; Houten, Verbraeck, Boyson, & Corsi, 2005; Sessink, Beeftink, Tramper, & Hartog, 2003; Sessink, Beeftink, Tramper, & Hartog, 2004; Sessink, Beeftink, Tramper, & Hartog, 2006; Sessink, Beeftink, & Hartog, 2005; Sessink, Beeftink, Tramper, & Hartog, 2007; Sessink, van der Schaaf, Beeftink, Hartog, & Tramper, 2007; van der Schaaf, Hartog, & Tramper, 2008; van der Schaaf, Tramper, Hartog, & Vermuë, 2006; van der Schaaf, Vermue, Tramper, & Hartog, 2003; van der Schaaf, Vermuë, Tramper, & Hartog, 2006; Vonder, Hartog, Clevers, & Lammeren, 2000; Wilmsen, Bisseling, & Hartog, 2002).

As the first initiatives were aimed at Food and Biotechnology, these projects were collectively referred to as 'FBT projects'. Although soon other fields became involved, the term 'FBT projects' is still used to refer to all these projects. Thus, the reader should keep in mind that 'FBT' is not a direct acronym for Food and Biotechnology anymore. The primary designers/developers in these projects were mostly PhD students with a master degree in a field that had considerable overlap with the subject matter on which the projects were focused. They had a position in the group of a chair holder who was responsible for the courses for which materials were designed and realized.
Within these FBT projects, methodological issues turned out to require considerable time. Methodological literature on design-related research in the fields of information systems and education shows that articulation of a design-related research approach is not trivial. First, emerging views on design science research in information systems (IS) research and on design research in education will be discussed. Next, section 4 tries to answer the question as to what extent these emerging approaches match the context of faculty-based design, realization, implementation, use and evaluation of digital learning materials in higher education. In section 5, the discussion is placed in a wider perspective of changing conceptions of science. Finally, we conclude that there are a number of reasons to define a new category of design-related research and that most likely such a new category cannot be articulated in an abstract fashion, i.e. without examples of publications that fit this category. Rather, it is likely that such a category will have to be described as the union of elements found in publications that are de facto recognized as faculty-based and oriented towards design.

2 Emerging views on design science research in information science

The term 'Design Science Research' (DSR) has several different meanings in various disciplines. This section shortly describes the development of the meaning of the term Design Science Research in Information Science (IS). In the remainder of this article, the term Information Systems Design Science Research and the acronym ISDSR will be used.

2.1 Information Systems Design Science Research (ISDSR)

For information technology, March and Smith (1995) have presented a framework for classifying research based on a process dimension with four activities ('build' , 'evaluate', 'theorize' and 'justify') and a product dimension with four output-classes ('representational constructs', 'models', 'methods' and 'instantiations'). The authors clarify that the term 'representational construct' is used to refer both to formal concepts such as 'entity', 'relationship', 'constraint', as well as to less formal concepts such as 'participation', 'satisfaction'. Furthermore, within the context of this article, one can interpret 'instantiations' as realizations of a design.
The four activity types and the four output-classes constitute a framework of sixteen cells. March and Smith take the position that activities in each cell can contribute scientific knowledge and each cell "describes viable research". The eight 'build' and 'evaluate' cells are labeled 'design science research'.

2.1.1 Outputs of ISDSR

March and Smith (1995) note that perspectives in information technology literature and computer science literature are different: "While there is little argument that novel constructs, models and methods are viable research results, there is less enthusiasm in information technology literature for novel instantiations." However, "Reaction is quite different in the computer science literature where the key determinant of the value of constructs, models and methods is the existence of an implementation (instantiation)." And about instantiations: " ..., the aim is to determine 'how well' an artifact works, not to prove anything about how or why the artifact works." Finding out why an artifact 'works' is a matter of additional research aimed at progress of the IS discipline.
More recently, Hevner, March, Park and Ram (2004) highlighted that one should rather consider two complementary paradigms as primary relevant in IS research. These are labeled as the 'behavioral science paradigm' and the 'design science paradigm' (i.e. the ISDSR paradigm). The output of ISDSR are "IT artifacts intended to solve identified organizational problems" and corresponding evaluations. Moreover, the artifact "… must be described effectively, enabling its implementation and application in an appropriate domain." The authors refer to a range of examples highlighting that demonstrating the feasibility of realizing an artifact that can 'work' is characteristic for the type of ISDSR that focuses on new problems. However, the authors stress that goal of ISDSR is 'utility' and recognize that "an artifact may have utility because of some yet undiscovered truth."

The authors essentially describe the IS knowledge base by describing its content categories. The first main category is foundational and includes theories, frameworks, instruments, constructs, models, methods and instantiations. The second main category is methodological and includes data analysis techniques, formalisms, measures and validation criteria. IS Research implies: contributing to this knowledge base. In other words, in addition to the main output-class of artifacts, the content categories are also output-classes. In contributing to the knowledge base, the behavioral science paradigm and the design science paradigm should be considered complementary.

Hevner et. al. present a set of output requirements. In particular, the artifact should be a solution of a new problem or be a better solution for a previously solved problem. The artifact must be "rigorously defined, formally represented, coherent, and internally consistent" and "the results must be communicated effectively." Evaluation must be based on appropriate metrics and data. Actually, the authors use the term 'guidelines' instead of 'requirements' and add that the guidelines do not have to be obeyed strictly in order for research to be classified as ISDSR. Thus, term 'guidelines' instead of 'requirements' suggests that the authors want to avoid the more strict interpretation of the latter.

2.1.2 ISDSR process

In (Hevner, March, Park, & Ram, 2004; March & Smith, 1995) no specific description of a process model for ISDSR is described, but more recently Peffers, Tuunanen, Rothenberger and Chatterjee (2007) do propose such a model. They adopt the output-classes defined in (Hevner, et al., 2004) and emphasize that their supplementary process model must be viewed against the background of a mental model in which "outcomes from DSR are clearly expected to differ from those of theory testing or interpretative research." The proposed process model, which is called design science research methodology (DSRM), is presented as just one of several imaginable models and not as a singular model that defines ISDSR.

The proposed process model is based on the union of the core activities in a selection of the literature (Archer, 1984; Cole, Purao, & Rossi, 2005; Eekels & Roozenburg, 1991; Hevner, et al., 2004; Nunamaker, Chen, & Purdin, 1991; Takeda, Veerkamp, Tomiyama, & Yoshikawa, 1990; Walls, Widmeyer, & El-Sawy, 2004) and consists of six activities. These activities are 'identify problem and motivate', 'define objectives of a solution', 'design and development', 'demonstration', 'evaluation' and 'communication'. Although the activities are presented in a sequence, the authors stress that a design process may start anywhere in the sequence and move 'outward'. Thus, an approach might be 'problem-centered', 'objective-centered', 'design-and-development-centered', but also 'client-content-centered'. The authors distinguish two types of 'iteration': iteration in the search process as well as iteration towards other activities after evaluation. Because iteration of the second type is considered important in design-related research approaches that will be discussed in section 3, it is notable that Peffers et.al. allow for iteration but do not require iteration as a necessary characteristic of an ISDSR project. Four case studies are used to illustrate the applicability of the process model.

3 Emerging views on design research in educational sciences

3.1 Developmental or development research

In educational sciences, the terms 'development research', 'developmental research', 'design and development research' and 'development studies' have been used for a long time with many different meanings. Originally, 'developmental research' was closely related and particularly important in the field of instructional technology. Richey (1994) adopted the following definition: "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet criteria of internal consistency and effectiveness." Richey described 'developmental research' as an alternative for those situations where straightforward instructional design was not applicable. As a research methodology Richey considered 'developmental research' "very unclear", even though it had already a long history. Five years later, van den Akker (1999) refers to the situation with respect to 'design and development research', 'design experiments' and 'design research' as "an emerging trend, characterized by a proliferation of terminology and a lack of consensus on definitions" and "rather confusing".

3.1.1 Outputs of development research

One output-class of development research in (van den Akker, 1999) is evidence of practicality and effectiveness of the realized design implemented in real life settings. Other outputs are more "generalizable" outputs, which are considered to be "more scholarly". In particular, these are design principles and theoretical design rationale. Here, a design principle is a heuristic statement that says: If you want to design an intervention for a specific purpose or function in a specific context, then "you are best advised to give that intervention the characteristics A, B, and C " … "and to do that via procedures K,L,M " … "because of arguments P,Q,R." The term 'intervention' is used as a "common denominator for products, programs, materials, procedures, scenarios, processes and the like". The author states that design principles will have more weight to the extent in which they are evidence-based and justified by theoretical arguments. Moreover, they will be "additionally powerful if they have been validated in successful design of more interventions in more contexts". In (van den Akker, 1999), validity "refers to the extent that the design of the intervention is based on state-of-the-art knowledge ('content validity') and that the various components of the intervention are consistently linked to each other ('construct validity')". However, it is not immediately clear how to apply this definition to a design principle. Moreover, experimental approaches to validation would be problematic for a design principle that rests on a small subset of all relevant variables if many variables outside this subset cannot be controlled.
One of the main types of development research are 'reconstructive studies' (Richey, Klein, & Nelson, 2004; van den Akker, 1999). These are conducted during or after development of several interventions. Reconstructive studies may produce articulations of design principles, new design -, realization -, and evaluation procedures and/or models, conditions that facilitate their use and generalized conclusions. Other main types of development research include 'Formative Research', which aims to optimize the quality

of an intervention (van den Akker, 1999) and projects that produce lessons learned from a specific development in a specific context (Richey, et al., 2004).

3.1.2 Development research process

Van den Akker (1999) regards formative evaluation as key activity in development research and refers the reader to the existing body of literature on formative evaluation. In particular, formative evaluation is aimed to generate suggestions for improvement. This requires 'richness of information' and at the same time smart methods to manage this richness. In this context, examples of 'rich information' are for instance results of observations or interviews. Such richness is considered more important than standardization of data collection methods. In addition, it is suggested that richness of information is difficult to combine with large samples of situations and/or participants. In a review of representative development research (Richey, et al., 2004), the following research methods were identified: ‘case study’, ‘descriptive’, ‘ethnography’, ‘evaluation’, ‘experimental’, ‘historical’, ‘observational’, ‘philosophical’, ‘qualitative’, ‘survey’ and ‘other’. Listing these terms all under the generic term 'research methods', obscures that many of these terms imply not only different approaches, but also different goals and outputs. Most of these outputs are indeed likely to be of the type that is called 'rich information' here. In the same review article, the authors also discuss theoretical orientations on design, studies of design and designer decisions and the development of tools and systems that support the instructional design process. This research fits primarily reconstructive studies. As to tools and systems that support the instructional design process they also recognize developmental research that describes and analyzes design projects in which such automated tools are used and in which the impact on learners of the materials produced using these tools are evaluated. More recently Richey et.al., (2007) explicitly dropped the term 'developmental research' in favor of 'design and development research'. They propose now to distinguish two clusters of such research: 'product and tool research' and 'model research'. The latter tends towards reconstructive studies.

3.2 Design experiments

A considerable part of what others now would call 'design research' (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) falls outside the scope of (Richey & Klein, 2007). In particular 'design experiments' literature and 'design-based research' literature and several research approaches that previously have been labeled 'developmental' such as described in (Lijnse, 1995, 2003) respectively in (Gravemeijer, 1994; Gravemeijer, 1998) are not covered. Both Lijnse (2005) as well as Gravemeijer (2006) now use the label 'design research' and use this label in a way that is more closely related to the 'design experiments'. Current literature in educational design research mostly traces the term 'design experiment' back to (Collins, 1992) and (Brown, 1992). Several authors more or less equate design-experiments with design research or with design-based research. For instance Cobb et. al. (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) use the terms "design researchers" and describe design experiments as "innovative and design-based".

3.2.1 Outputs of design experiments

The implied output of design experiments as described in (Brown, 1992) is evidence for a specific improvement and a theoretical rationale "why things work".
According to (Cobb, et al., 2003) the intended output of design experiments are "humble theories" about "learning and the means that are designed to support that learning." These humble theories will be domain-specific and may be aimed at any level of aggregation from the individual student to the classroom and even to a school district. Lijnse - originally using the term 'developmental research' (Lijnse, 1995, 2003) - later adopting the term 'design research' (Lijnse, 2005) describes as outcomes "exemplary teaching materials and teacher guides", "domain specific didactical theory and didactical structure", and "domain independent didactical structure". From an information sciences perspective, the domain specific 'theory' can be regarded as an instantiation of the domain independent theory. An example of the latter is a 'problem-posing approach' (Lijnse & Klaassen, 2004). One characteristic of such an approach is a sequence in which - depending on the state of knowledge of the student - each time when a student's knowledge has become 'stable' a new problem is presented that for the student should become a motive to adjust or reconstruct his knowledge (see also Aegerter-Wilmsen, Coppens, et al., 2005; Aegerter-Wilmsen, Janssen, Hartog, & Bisseling, 2005; Aegerter-Wilmsen, Janssen, Kettenis, Sessink, Hartog, & Bisseling, 2006). Lijnse (2003) emphasizes that a ‘didactical theory’ differs essentially from what natural scientists are used to regard as a theory. Core concepts in a didactical theory are mental concepts such as 'belief', 'desire', 'meaning', 'intention'. The theory must be adequate for understanding and guidance of the classroom process.
In (Gravemeijer & Cobb, 2006) a different description of the intended output of educational development research or design research is given. From an information sciences viewpoint an important intended output of developmental research or design research as described in (Gravemeijer & Cobb, 2006) can be regarded as a tested qualitative model of a student or of a class of students. This model should be able to describe what the relation is between events and the successive 'states' of the student or class and to predict new states and events. The model must also take into account elements such as 'classroom culture'. Here it is relevant to recall that Hevner et. al. (2004) acknowledge two complementary research paradigms in IS research: an ISDSR paradigm and a behavioral science paradigm. They describe the intended outputs of research in the complement of ISDSR, i.e. in the behavioral science paradigm as 'verified theories'. These theories "explain or predict human or organizational behavior."

3.2.2 The process of a design experiment approach

Several authors provide extensive accounts of processes involved in preparing and conducting design experiments.

Brown (1992) describes design experiments as complex intervention studies in real classroom settings and emphasizes that in a design experiment many variables are changed at the same time while the researchers look for effects in many variables as well. Moreover, many of the variables are likely to be in knowledge domains in which an educational researcher has not been trained. The design requires much more than available theory can provide.

Assessment data include data from short answer quizzes in pre - and post-tests, but also a variety of quantitative and qualitative data. Brown mentions transcripts of children's activities; observations of teachers' coaching and teaching, ethnographic observations of group discussions, planning sessions, peer tutoring sessions, scorings of e-mail queries to peers and teachers, and finally extensive video and audio taping of individuals, groups, and whole classroom settings.
Brown stresses that design experiments involve a number of challenges with respect to issues such as sampling, confounding, researcher bias, handling massive amounts of data and scaling. However, that holds for any research method that tries to model education (Kelly, 2006).
Gravemeijer et. al. (2006) describe the process of educational design research in terms of three Phases: (1) preparation of a design experiment, (2) experimenting in the classroom, (3) retrospective analysis. In Phase 1, the domain-specific learning goals must be formulated and the teacher must probe the students' understanding as consequence of students' prior instruction. Next, a 'local instruction theory' must be formulated consisting of conjectures about a possible learning process and about possible supporting means. In this phase 1, also the theoretical intent of the research must be formulated in order to focus investigations. This theoretical intent might be to develop new concepts and a new conceptual framework to describe and interpret classroom discourse. Eventually it should be possible to see classroom events as paradigm cases. In Phase 2, the actual design experiment consists of 'micro-cycles' of thought experiments followed by enactment of instructional classroom activities and analysis of observations. The thought experiments are based on the conjectures. The experimental results in a micro-cycle or in retrospective analysis of the design experiment may show that the conjectures have to be adjusted. Next, a new design experiment can be designed. A series of design experiments can be regarded as a series of 'macro-cycles'. More or less in the same vein, Lijnse (2003) proposes to think in terms of 'hypothetical scenarios' that can be tested empirically.

From a computer science perspective, one sees a resemblance of the approach described in (Gravemeijer & Cobb, 2006) with the well known approach of designing and realizing a simulation model, and comparing results of simulation experiments with results of experiments in reality. In particular, classroom experiments suggest agent-based simulation models. Gilbert (2008) defines agents as follows: "Agents are either separate computer programs or, more commonly, distinct parts of a program that are used to represent social actors - individual people, organizations such as firms, or bodies such as nation-states. They are programmed to react to the computational environment in which they are located, where this environment is a model of the real environment in which the social actors operate". Moreover, "A crucial feature of agent-based models is that the agents can interact, that is, they can pass informational messages to each other and act on the basis of what they learn from other messages. [...]"

3.3 Design-based research (DBR)

Another design research approach is design-**based** research (DBR) in education (Bell, Hoadley, & Linn, 2004; Design-Based Research Collective, 2003; diSessa, 2000; Hoadley, 2002; Marcia C. Linn, Elizabeth A. Davis, & Philip Bell, 2004).

3.3.1 Outputs of DBR

For DBR as defined in (Design-Based Research Collective, 2003), outputs are: learning environments, shareable theories, communications of implications of these theories to practitioners as well as to other educational designers, explanations of how designs function in authentic settings and well documented successes and failures. According to Bell, Hoadley and Linn (2004, p. 77) DBR also delivers results of testing theoretical accounts of learning, cognition and development.

3.3.2 The DBR process

The DBR Collective characterizes DBR as a process in which design and theory development are "intertwined". The process consists of continuous cycles of "design, enactment, analysis and redesign". This requires adequate methods for documentation in order to be able to make the connection between actual enactment and intended outputs. Bell, Hoadley and Linn (2004, p. 77) emphasize that DBR "includes testing theoretical accounts of learning, cognition and development by using theory to design or engineer instruction and conducting empirical studies of the instruction in a naturalistic setting." Furthermore, “design research includes compelling comparisons in which two forms of innovation are enacted under otherwise similar conditions." The authors refer to several chapters in (M. C. Linn, E. A. Davis, & P. Bell, 2004) for examples of compelling comparisons. For instance, E.A. Davis (2004) compared the effects of generic prompts and the effects of directed prompts with respect to promotion of productive learning outcomes within a given digital environment (KIE-Research-Group, 1997). This digital learning environment was already designed and developed, and in operation (see also Davis, 2003).

3.4 Educational design research (EDR)

Over time, several researchers started to use terms such as development(al) research, DBR, design research and design experiment as equivalent or almost equivalent. Others decided to re-label their research approach. A few years ago the term educational 'design research' (EDR) was proposed as a common label for a family of related educational research approaches such as those in the previous sections but not necessarily limited to those described in (van den Akker, et al., 2006). Like seven years before in (van den Akker, 1999) the authors observe still an "emerging trend", in which terminology is still not stable. Characteristics that most studies have in common are the following. The studies are 'interventionist', 'iterative', 'process-oriented', 'utility-oriented' and 'theory-oriented'. In these approaches, the focus is on understanding and improving interventions. In relation to this, the term 'process-oriented' is used to indicate that EDR should avoid "a black box model of input-output measurement".

3.4.1 Outputs of EDR

Van den Akker et. al. (2006) adopt the following definition from (Barab & Squire, 2004) as an umbrella that seems to cover the major part of the 'EDR family': EDR refers to "a series of approaches, with the intent of producing new theories, artifacts and practices that account for and potentially impact learning and teaching in naturalistic settings." This definition essentially defines the intended output of EDR. However, the related literature tends to imply the intention is not 'theories or artifacts and practices', but rather 'theories and artifacts and practices'.
Kelly (2006) gives an overview of EDR output-classes ("genres in design research deliverables"). Some of these match well with the IS concept of artifact. These are: "curricular materials", "assessment task redesign", "software and associated curricular supports", "learning environments", "putatively more 'adoptable' products for teachers". Others are: "explanatory frames or interpretive frameworks in future research efforts" and a number of 'genres' that refer to 'theory' and 'understanding' such as 'local theory', 'humble theory', and 'better understanding' of a process.

3.4.2 The EDR process

In (van den Akker, et al., 2006), the process of educational design research is characterized as 'interventionist' (i.e. aimed at "designing an intervention in the real world") and 'iterative' (i.e. incorporating "a cyclic approach of design, evaluation and revision").
It should be noted though, that the operational meaning of the term 'iterative' in different projects still implies a wide variety. Compare for instance the description of the process in (Gravemeijer & Cobb, 2006) of which a short impression has been given in section 3.2.2, with the iterative process in the CASCADE-SEA project as described in (McKenney & van den Akker, 2005).

The CASCADE-SEA project involved the design, realization and evaluation of the CASCADE-SEA system. This system supports teachers in making exemplary, reusable paper-based lesson plans and teacher guides. In this process, 34 'data collection circuits' were identified. A 'circuit' could be a meeting or seminar, but also an extensive formative evaluation of a prototype. The 'size' of a circuit ranged from half a day to one month. A circuit involved one or more of the following data collection strategies (a) screening, (b) expert appraisal, (c) microevaluation (i.e.outside the intended setting), and (d) tryout. A circuit produced recorded data. For data collection 108 instruments were used categorized in terms of (a) interview and walk-through schemes; (b) questionnaires; (c) discussion guides; (d) observation and demonstration schemes; (e) logbooks; and (f) document analysis checklists. All in all the total number of respondents was about 510. We understand that about 60 of the respondents were experts. Four prototypes were made and evaluated.

4 Applicability in faculty-based projects on digital learning materials

4.1 Output-classes of ISDSR, EDR and of faculty-based projects

This section attempts to answer the question to what extent output-classes that have been defined for emerging approaches discussed in the previous sections match the context of faculty-based design, realization, implementation, use and evaluation of digital learning materials in higher education. This section will just refer to ISDSR and EDR, where the latter should be understood to include development(al) research unless specified otherwise.

Much of the output of faculty-based design-oriented research of the type that is described in the publications listed in the introduction fits one or more of the output-classes listed in (Hevner, et al., 2004). In particular, the primary and required output consists of one or more artifacts and instantiations and the primary focus is on evidence of utility. All publications also deliver output in one or more of the additional ISDSR output-classes, in particular frameworks or architectures, instruments, constructs, models, methods. Delivery of output in each output-class is not a strict requirement for research to be categorized as ISDSR. Thus, one might regard faculty-based design-oriented publications on digital learning materials that are listed in the introduction, as ISDSR publications. However, as a characterization of faculty-based design-oriented research output, some important output-classes are insufficiently visible in (Hevner, et al., 2004) and (Peffers, et al., 2007). In our view, at least design requirements (see for instance Lamsweerde, 2001) and a description of the implementation should be considered more explicitly as an output-class. Design requirements should be made explicit and formulated operationally because they are needed to show that the project goal has been achieved!

While 'theory' is one of the foundational categories in IS research, contribution to theory is not required as output of ISDSR. In contrast, in the EDR community the requirement that output must contribute to 'understanding', 'theory' and include 'heuristic design principles' is in general given considerable weight. It should be noted though, that all design-related research approaches reviewed in this article leave openings for research that does not satisfy the output requirements or process requirements of the approach.

As to heuristic design principles, it should be emphasized that it will seldom be possible to test a design principle or a small subset of design principles in a case study in a faculty-based project. This problem is closely related to the difficulty of 'isolating' variables (van den Akker, 1999). As in design-science research projects, also in a faculty-based design-oriented project, researchers can conjecture some design principles or design heuristics. However, in faculty-based design-oriented projects, delivery of such

principles appears not to be the primary aim. In particular, additions to the set of design principles and heuristics appears not to be strictly required as output of a faculty-based design-oriented project.
Richey et. al. also included a discussion of synthetic and knowledge-based aspects of design, development and evaluation of computer assisted (instructional) design tools and knowledge engineering tools. In several of the FBT projects, development of such tools has occurred (Kassahun, Beulens, & Hartog, 2006; Olivier D.T. Sessink, et al., 2007; van der Kolk, Beldman, Hartog, & Gruppen, 2008; van der Schaaf, Tramper, et al., 2006). An important point is however that, from the viewpoint of involved faculty, this is not the primary intention. Apart from some exceptions, the development of such tools implies that center of gravity of the investments drifts away from the involved subject matter discipline.

4.2 Processes of ISDSR, EDR and of faculty-based projects

The question is now to what extent processes that have been described for emerging approaches as discussed in sections 2 and 3, match the context of faculty-based design, realization, implementation, use and evaluation of digital learning materials in higher education.

4.2.1 No 'reconstructive studies' or model research

The main activities in a faculty-based project on design, realization, implementation, use and evaluation of digital learning materials in higher education are not the main activities in 'reconstructive studies' or 'model research' as described in (Richey, et al., 2004; van den Akker, 1999) and (Richey & Klein, 2007) respectively. Thus, from an EDR point of view, those faculty-based projects cannot be considered as 'reconstructive studies' or 'model research'. From an IS research point of view, 'reconstructive studies' and 'model research' rather fit traditional IS research, in which the study of existing systems and processes is relatively important, and not an emerging design science research paradigm nor a faculty-based design-oriented paradigm.

4.2.2 Implementing digital learning material versus implementing interventions

Implementation of an information system is closely related with interface definitions. The interface of a system describes a set of assumptions about the environment of the system and a definition of the function(s) of the system. Implementation is then defined as fitting the instantiation to its intended context. It can occur that some of the initial assumptions about the intended context of the information system or more specifically the (digital) learning material turns out not to hold by the time the design has been realized. Thus, it can occur that implementation of digital learning material within a course may require adjustments of the context.

In contrast, in much of the EDR and model research literature, 'implementation' refers to implementation of an intervention or even a program of interventions and the central idea is that of practitioners acting in accordance to a process model. In educational literature, one often encounters the term 'enactment' to describe the relationship between the actual acts and the model.

Earlier it was noted that 'interventions' in (van den Akker, 1999) include 'products' and 'materials'. However, it is quite uncommon to refer to the use of a digital tool in education as an 'intervention'. The term 'interventionist' tends to suggest a picture in which the roles of researcher and practitioner are allocated to different persons and where persons with a researcher role perform an intervention in a process that would normally be under responsibility of persons with a practitioner role. Such a picture does not fit the case studies in which faculty carries out a summative evaluation of specific digital tools or learning materials in their own courses. The operational meaning of 'implementation' of products or tools in the context of such case studies is different from the operational meaning of 'implementation' in the context of an intervention program. In the faculty-based case studies, implementation should be regarded from the same viewpoint as that of an end-user who implements a computer application in his own work. In line with this, the distinction between 'model research' and 'product and tool research' (Richey & Klein, 2007) supports awareness of the actual difference in practice between implementing products and tools and implementing an intervention. Indeed, the general picture that arises from IS textbooks of implementation also reflects this difference between implementation of end-user applications such as a spreadsheet program, which is often just made available, and interventionist implementation of information systems such as an enterprise resource planning system, which goes hand in hand with implementation of a new business processes.

Thus, we conclude that it is better not to classify faculty-based projects on design, realization, implementation, use and evaluation of digital learning materials as 'interventionist'. In addition, the operational meaning of "implementing digital learning materials in a course" should be recognized as different from the operational meaning of "implementing an intervention program in an educational system". In the former, the term "enactment" is not useful, in the latter, the term "enactment" can be a useful term.

4.2.3 Balancing availability of resources to faculty intentions

Any advance in the 'scholarship of teaching' requires an acceptable balance between costs and practical benefits as well as acceptance of the resource constraints in faculty-based projects. For instance, it is unlikely that design experiments as described in (Brown, 1992) can be done in a faculty-based context. In such design experiments, most of the resources would go into the 'enactment' of the experiment and into the management and analyses of a huge body of diverse data. In contrast, in a faculty-based project, the stakeholders are likely to desire that most of the resources will be allocated to design and realization of learning materials. In such projects, the center of gravity of investments must be close to subject matter knowledge domains of those faculty who are going to invest much of their time. This is because in general, it seems unlikely that faculty will be willing to invest considerable attention and departmental resources in activities that are far from their own knowledge domain. If they would do so they would also be in danger to loose contact with their own discipline.

4.2.4 Stages with iteration

A sequential process diagram as presented in (Peffers, et al., 2007) with five research entry points from which the researcher can 'work outward' combined with 'iteration' can easily become confusing. In practice, a Gantt chart like representation of activities that are allowed to overlap in time seems to be more realistic. In particular, such a representation does not require an 'escape' such as for instance the introduction of 'iteration'. On the other hand, the different viewpoints suggested in (Peffers, et al., 2007) such as 'problem-centered', 'objective-centered', 'design-and-development-centered' and 'client/context-centered' are each applicable in faculty-based projects.
In ISDSR (Peffers, et al., 2007) ‘implementation’ is not an explicit process step but two process steps, 'demonstration' and 'evaluation', do refer to implementation. Peffers et. al. suggest that publications might be structured according to the given process model. However, the fact that implementation is not considered as a distinct main activity might obscure a description of implementation in publications. Lack of clarity about initial assumptions that turned out not to hold, and for which the design, or the realization or the context was adjusted, will make it difficult for readers of publications to make their own evaluation.

4.2.5 Faculty-based contexts provide little opportunity for formative evaluations

With respect to evaluation, it is usual to distinguish summative evaluation and formative evaluation. Summative evaluation is intended to answer the question if the goal has been achieved. Formative evaluation is intended to provide information that can help us to make improvements in order to come closer to the goal (Verschuren & Hartog, 2005). In ISDSR, formative evaluation is not mentioned. In contrast, formative evaluation is very prominent in EDR and one of the main categories of EDR is called 'formative research'. Moreover, descriptions of the formative research category tend to emphasize the role of 'rich information'.
It would be difficult to describe the type of faculty-based projects listed in the introduction as formative research projects. Formative research does not match well with the context and intentions of a faculty-based project that should deliver digital learning materials for three reasons. Firstly, the primary stakeholders in these faculty-based projects will require that most of the research effort goes into design (including articulation of the design goal) and into realization. In such projects, there is only very little room to allocate efforts to the collection and interpretation of rich information. Secondly, there is little opportunity for much formal formative evaluation. This is partly due to the dominance of the university course schedule. Another factor is to the limited timely availability of good samples of the intended student population and experts for such formal formative evaluations. The most natural timeslot for the project is the period between two instantiations of the course in which the learning materials can be used. In

many universities, this will be a period of one year. This also implies a hard deadline. If that deadline is missed, an opportunity for summative evaluation is missed and the project will loose too much momentum as well. Furthermore, a missed deadline will imply that the design and realization time is spread out over almost two years and this will induce too many discussions on changes of available technology and infrastructure within the project. Clearly, the situation in a faculty-based project is with respect to timely availability of experts different from projects on secondary education. In fact, comparable difficulties in realizing formal formative evaluations have been reported in a study in the way of working of instructional designers (Visscher-Voerman, 1999). In practice, the number of formal formative evaluations in the FBT projects varied across the projects, but the number was always considerably smaller than in a project such as the CASCADE-SEA project (McKenney & van den Akker, 2005). In line with findings in (Visscher-Voerman, 1999), the FBT projects also included a range of less formal formative activities. Examples of informal formative activities are hoc e-mail, chat or telephone communications on specific elements or aspects of web-based digital learning material in a specific state of development. Thirdly, the developments within a faculty-based project can also not be described in terms of a series of prototypes that were revised as a consequence of analysis of empirical data or expert reviews. In (Nieveen, McKenney, & van den Akker, 2006), a picture of typical development studies is sketched in which "setting out design guidelines" and "optimizing prototypes through cycles of design, formative evaluation and revision" have considerable weight. Rather, for the process in a faculty-based project on design, realization, implementation, use and evaluation the term 'satisficing' seems more adequate than 'optimizing'. "In a satisficing model, search terminates when the best offer exceeds an aspiration level that itself adjusts gradually to the value of the offers received so far." (Simon, 1978). In a satisficing model, relevant variables that define aspects and qualities of the digital learning material and the context in which it functions, will acquire an aspiration level. For a subset of these variables, the aspiration level will become part of the definition of the goal that is to be achieved. Moreover, an 'offer' does not have to be a tangible prototype. For instance, an 'offer' can refer to a possible choice with respect to a part of the abstract design. The first real life situation in which the material is implemented and in use, is then the context for a summative evaluation of the materials. The intention of the FBT projects was that there would be one realization of the material and that a fundamental revision of the material once it has entered its first real life test would not be necessary. Most of the FBT materials are indeed still functioning in the way they were first conceived. This does not mean that there is no room for improvement. However, instead of optimization, a characteristic of the processes is that allocation of additional efforts to improvement along a specific dimension stops once the aspiration level has been reached. Instead of optimizing within a project or along a specific dimension, it is usually decided that the same amount of capacity can induce more benefits by reallocation of capacity to new dimensions, topics or projects (see figure 1).

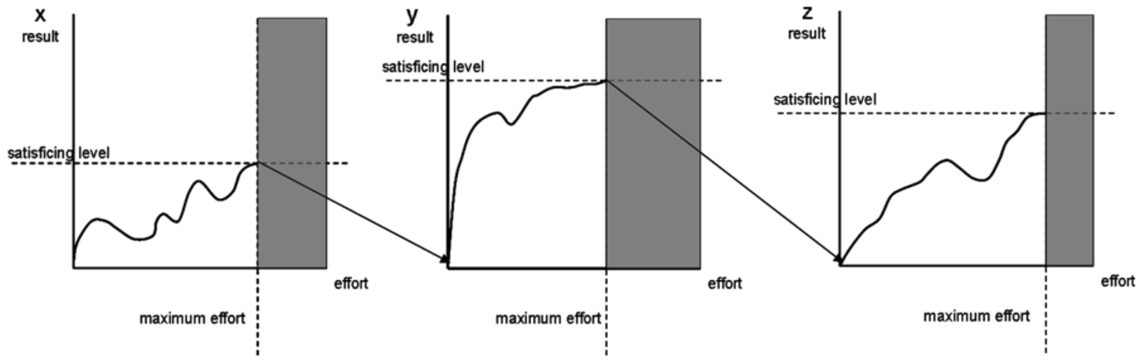

Figure 1 This figure illustrates searches along different dimensions in a satisficing model. In particular, allocation of additional efforts to improvement along a specific dimension stops once the satisficing level has been reached. The vertical 'result' axes in the figure will in general refer to composite dimensions, i.e. to parts of the design.
Note that this figure only refers to variables with ordered domains.

Of course, a summative evaluation of a module of learning material can produce a 'negative' outcome. However, such an outcome does not convert a summative evaluation automatically into a formative evaluation. Formative evaluation is intended to provide handles for improvement (see for instance Verschuren & Hartog, 2005). Some of the summative FBT evaluations also provided reasons for improvement. However, the evaluation of first real life use of the materials was almost always intended to be a summative evaluation and defined and organized as such. Resulting reasons for improvement were not automatically suitable handles for improvement.
Finally, a problem in faculty-based projects is that formative evaluation methods as well as the methods that emerged from the review of developmental research in (Richey, et al., 2004) and listed in section 3.1.2, are not intended to support the synthetic aspect of design research. Moreover, these methods are likely to be unfamiliar to many designers with a natural sciences or engineering background.

4.2.6 Insufficient reasons to highlight 'iteration' in faculty-based projects on digital learning materials

While iteration often is introduced to match a sequential process description with a reality that is much less sequential (Peffers, et al., 2007; Verschuren & Hartog, 2005) the term 'iterative' is in EDR used as a process characteristic. However, as such, it applies to almost any design project including information systems development projects, as well as to almost any research project (see for instance Denning, Comer, Gries, Mulder, Tucker, Turner, et al., 1989; Eekels & Roozenburg, 1991). Interpreted in this way, 'iterative' is not a characteristic that is very distinguishing. In projects on design and development of information systems 'iteration' is also often associated with further articulation or

adjustment of operational design requirements and with adjustments of the intended functionality. From an IS viewpoint, 'iteration' often can be viewed as backtracking in a tree search process. In, or after, such a process one might want to study a trail of the tree search process and to document when and why it was decided to backtrack. Backtracking decisions can be made based on experiences, on comments by peers, or on many other types of information sources. Consequently one may expect that at a detailed level 'iterative' in one approach considerably differs from 'iterative' in another approach. For instance, many of the ‘data-collection circuits’ in (McKenney & van den Akker, 2005) are different from 'micro-cycles of thought experiments followed by enactment of instructional classroom activities’ in (Gravemeijer & Cobb, 2006).
While some forms of 'iteration' will occur in faculty-based projects as in any real life project, we would not promote 'iteration' as a distinctive characteristic of faculty-based projects on design, realization, implementation, use and evaluation of digital learning materials.

4.3 Design rationale management and knowledge management

Iteration and formal and informal formative evaluations can also be viewed from the perspective of 'design or decision rationale management'. This involves activities such as recording, capturing, representing and managing design rationale for reuse and the design and construction of information systems that support these activities (Dutoit & Paech, 2000; Hammond, 1994; Hordijk & Wieringa, 2006; Regli, Hu, Atwood, & Sun, 2000). Regli et.al. regard design rationale as a subproblem of the broader area of knowledge management. Van Aalst and van der Mast (2003) describe and evaluate a knowledge management system named ‘Performer’ that supports members of multidisciplinary courseware development teams. In particular, ‘Performer’ enables team members to share templates and best practices and experiences. The courseware development projects that were studied were mostly aimed to support training in departments of large organizations or enterprises. The knowledge management system was intended to support teams of five to eight team members with different disciplinary backgrounds. The findings suggest that, in an industrial courseware development environment, the efforts of data entry in such a system and the capturing and managing of experiences while being a “high risk investment” can provide “more positive project experiences”. Much of the relevant knowledge would be difficult to manage in a more traditional way. It is likely that the benefits of investing in the use of such a knowledge management system become more clear to the extent in which project teams are larger and involve more disciplines. Many faculty-based projects will not be of the size of the projects in which ‘Performer’ was used. Thus, the probability that design rationale and intermediate experience can be reused **within** the project is relatively low. Also, the teams in faculty-based projects will usually not involve so many disciplines.
These two points make it less attractive to spent faculty-based resources on implementation and use of a design rationale and/or knowledge management system.
For some EDR projects it might be useful to invest in design rationale management and knowledge management. In EDR projects reflection on design rationale and intermediate experiences is of primary importance. Thus, the investment of efforts in recording and

capturing design rationale, templates and experiences matches more directly with the primary intentions of an EDR project.
One should be aware though, that not all recording and data capturing with respect to design rationale has to be expensive. Experience in the FBT projects implies several low-cost options for recording and capturing, some of which bear resemblance with recording and data capturing instruments used in the CASCADE-SEA project (McKenney & van den Akker, 2005). In the FBT projects, the main instruments for data collection were questionnaires, exam questions, discussion guides (i.e. documents to structure a meeting: agenda plus explanation), logbooks, a version control system, software documentation and e-mails. Relevant differences between the FBT projects and the CASCADE-SEA project with respect to recording and data capturing are in the use of a version control system, in software documentation and in the use of e-mail.

Of course, the disadvantage of a large body of e-mail is that it would require considerable effort to analyze such a body and to extract from it reusable design rationale. On the other hand, any structure that would have been defined in advance would probably also work as a filter with respect to unforeseen categories of remarks and arguments. Thus, with respect to capturing rich information in the form of e-mail communication, faculty-based projects do not have to be different from EDR projects. For instance, in the FBT projects the number of e-mails between the main designer/developer and the program manager was about 500 e-mails (of varying length) per year. Much of this communication was based on the particular status of a particular module of digital learning material that was being designed and developed at the time. Differences between faculty-based projects and EDR projects do not have to be in the capturing of rich data. It is the activity of analyzing all these data in order to deliver reusable design and decision rationale and heuristic design principles, that does not match the primary goal of faculty-based projects.

4.4 The role and expertise of practitioners

One more important difference between faculty-based projects and projects implied in ISDSR and EDR, is based on the role and expertise of the practitioners. In faculty-based projects aimed to contribute to the scholarship of teaching the most important researcher is the practitioner and the most important target population of the publications are the peers of the practitioner i.e. other practitioners in the same discipline. Descriptions of EDR approaches in primary and secondary education suggest that responsibility for learning goals and learning processes comes into the hands of the research group (see for instance Gravemeijer & Cobb, 2006). In university education, the responsibility for the quality of the course and the selection and implementation of learning materials stays with the responsible professor and in general the student should take responsibility for his/her learning process. Finally, in faculty-based projects, the practitioners are themselves experienced researchers with an opinion on what constitutes valid knowledge.

In short, it is likely that the difference in role allocation in faculty-based projects on the one hand, and ISDSR and EDR projects on the other hand, is related to differences in intended outcomes. Related to this is the fact that the mindset of faculty will be based on a research paradigm that can be different from the educational research paradigm or the IS research paradigm.

4.5 Publishing research output of design-related research approaches

Against the background of the 'scholarship of teaching', it is important to point out that in the ISDSR process model much attention is paid to 'Communication'. In each case study discussed in (Peffers, et al., 2007) 'communication' involved publication in 'peer-reviewed scholarly journals' or 'refereed conference proceedings'. This fits the claim of the authors that their methodology aims to be a research methodology. While ISDSR might incidentally be applied for design, it is not primarily intended as design methodology. Design differs from design research in that "A design artifact, … is not necessarily required to embody new knowledge that would be conveyed to an audience through a scientific publication outlet."

In particular, ISDSR recognizes that aiming at scholarly peer-reviewed publications is different from just 'design'. This relates also to faculty-based efforts on design, realization, implementation, use and evaluation of digital learning materials that aim to share knowledge not only by making the resulting artifacts available, but also by means of publications that are reviewed by scientific peers. This suggests that such activities should inherit a name both from 'design' as well as from 'research'. In this respect, the publications listed in the first section of this article tend to match well with ISDSR. On the one hand, these publications fit in discipline specific education journals and discipline specific journals, which are read by faculty. On the other hand, these publications fit in journals in the area of Computers and Education or ICT in Education.

In contrast, apart from some exceptions (see for instance Strobel, Jonassen, & Ionas, 2008), EDR researchers primarily aim at disciplinary journals in education and ISDSR researchers primarily aim at journals in computer science, IS research, or related disciplines such as decision sciences or management sciences. In contrast to faculty-based projects on design, realization, implementation, use and evaluation of digital learning materials, both EDR as well as ISDSR in general aim their publications at a target population of which practitioners are not members.

Scholars adopting a design-related research approach are often warned that there will be publication barriers. Peffers et. al. (2007) highlight that diffusion of a DSR paradigm in IS research over the past 15 years has been slow. They emphasize the necessity of a common framework and corresponding template for ISDSR in order to support both readers of papers as well as reviewers. Collins, Joseph and Bielaczyc (2004) note that "The notion of design research … faces obstacles in the broader research community that make publication and tenure difficult for learning scientists." A little later, Reeves, Herrington and Oliver (2005) note that EDR is still so new that many journal editors and reviewers are unfamiliar with it." In addition, it is not easy to keep the research output within usual word count limits. Nieveen, McKenney and van den Akker (2006) note that "the majority of gatekeepers to funding and publication opportunities speak alternate 'research dialects'."

Roughly, two types of publication problems can be distinguished. One type of problems is based on the question what type of resulting knowledge should be considered sufficiently valid and sufficiently valuable to share with others. The other type is related to the fact that the bulk of 'rich information' and 'design rationale' does not fit the traditional research journal format. In the next subsection, these two types of publication problems will be discussed.

5 Discussion

Much of the lack of clarity and confusion about design-related research approaches can be attributed to the fact that new practices of research are likely to encounter different interpretations of basic primitives such as 'theory' and 'understanding'.

Different authors approach the concept of 'understanding' in different terms (see for instance Anderson & Krathwohl, 2001; Biggs & Tang, 2007; Gibbons, 1999; Simon, 1996; Simon, 2001; Ziman, 2002). Ziman (Ziman, 2002) p. 289 regards 'understanding' "a primitive notion, a brittle 'natural kind', that shatters under the impact of analysis." Moreover, in science 'understanding' refers usually to understanding within a community, often a discipline. When the term 'understanding' is used to highlight differences between research approaches, one of the questions will be if 'understanding' necessarily has to be based on the components of a specific disciplinary knowledge base.

In design, one often prefers to view a system as being composed of systems. When the composition is hierarchical, one can distinguish levels of systems (see for instance Simon, 1996). 'Understanding' might then be interpreted as 'having knowledge of the structure and the interfaces down to a specific level'. 'Deeper understanding' might then refer to depth in terms of ever deeper levels of such an hierarchy. Much of the literature on EDR suggests that the researcher should be aiming at ever 'deeper understanding'.

However, the alternative view of a design being based on assumptions, which are part of interfaces of resources, better fits the conditions of a faculty-based project. An example of such a resource could be a textbook on instructional design such as (Biggs & Tang, 2007; Merriënboer & Kirschner, 2007). Another example could be a specific scientific publication that implies a design requirement for specific learning materials (see for instance Evans & Gibbons, 2007; Means, Jonassen, & Dwyer, 1997). The better the interfaces of such resources, the less it will be necessary for the designer to look into the 'box' that belongs to the interface or to 'understand' what is inside the box (Simon, 1996). Most of the publications listed in the introduction apply implicitly such an interface view. In line with this, Gibbons observes " a shift within science from the search for ‘truth’ to the more pragmatic aim of providing a provisional understanding of the empirical world that ‘works'"(Gibbons, 1999).

Gibbons also states that the demarcation lines between basic research, applied research and product development are not clear anymore. This is in particular relevant with respect to faculty-based projects on design, realization, implementation, use and evaluation of digital learning materials. But it is also different from the intention that is described in (van den Akker, et al., 2006) as 'process oriented'.

Without a large number of paradigm examples, real differences between output requirements are difficult to capture because the terms to describe contributions are essentially what Ziman (2002) calls 'basic primitives'. In particular, 'theory', 'understanding', and 'contributing to theory' can have widely different meanings. Instead of 'theory', Kelly (2004) suggests to use working words such as " 'hypothesis', 'conjecture', 'observation', 'model', 'framework', 'explanation', 'belief', 'rationale', 'logical or argumentative structure', 'perspective', 'analysis', or 'synthesis'." Given the current state of emerging new research practices and in line with Kelly's suggestion, we do not want to impose 'contributing to theory' or 'delivering theory' as strict requirements for output of faculty-based design-oriented research projects.

As to 'rich information', one may question if it is really necessary to include such information in an article in a scientific journal. The fact that an article is based on a data set, possibly including a wide range of data types and that most of the raw data cannot be incorporated in the article should not be a barrier to publication. Raw data are seldom incorporated in an article. Apart from this, the data could be made accessible on the internet. What might be a problem is the question how to clarify the procedures for analysis and interpretation of 'rich data'. Apart from this challenge, the necessary resources for the design and execution of procedures for analysis and interpretation of 'rich data' are currently seldom available in faculty-based projects on design, realization, implementation, use and evaluation of digital learning materials.

Finally, the emphasis on 'iteration' in EDR approaches seems - rather implicitly - to be related to design rationale. What seems more important than iteration as a process characteristic is the extent to which iterations are reflected in publications. Thus, for the conceptually simple case of backtracking in a tree search, the question would be what reasons for backtracking are interesting enough to share with others and how to present these reasons for backtracking and the consequent new choices in publications.

Publishing design rationale for a specific set of design decisions in scientific journals will usually be impossible because of the difficulty of suitable decomposition. In this respect, design rationale involves the same problems as 'rich data' and very large simulation models. It seems to make more sense to share design rationale and other process knowledge by means of some design rationale or knowledge management system (see Regli, et al., 2000; van Aalst & van der Mast, 2003), which would be made accessible on the internet.

This holds much less for 'design patterns' because design patterns are suitable for publication in journals and books. A design pattern can be defined as a reusable configuration of basic components or activities (including parameter settings), which fits a partial design problem. The concept of design pattern was introduced more than twenty years ago in architecture (Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King, & Angel, 1977) precisely in order to share design knowledge in books and journals. Later the concept of ‘design pattern’ was widely adopted in software engineering (Gamma, Helm, Johnson, & Vlissides, 1994). Since then, several research projects in education and eLearning have produced and discussed many design patterns (see for instance Baggetun, Rusman, & Poggi, 2004; Busstra, Fesken, et al., 2008; Draaijer & Hartog, 2007; Fincher, 1999; Graham, 2003; Hartog, 2008; Hubscher & Frizell, 2002a, 2002b; Jegan & Eswaran, 2004; Kolfschoten, Lukosch, Verbraeck, Valentin, & Vreede; Mislevy, Hamel, Fried, Gaffney, Haertel, Hafter, et al., 2003; Rohse & Anderson, 2006; Scalise & Gifford, 2006). While this research can be linked to design-based research and educational design research (Winters & Mor, 2008), incorporating a discussion of design patterns in this article would have been far beyond its scope.

6 Conclusion

Those faculty who design, realize and use digital learning materials and want to incorporate their design activities in their 'scholarship of teaching' are likely to become aware of methodological issues that they do not encounter in their discipline. A number of these issues are related to the synthesis of design and research, and to the question, what this synthesis implies for sharing knowledge in publications in peer-reviewed scientific journals. Literature on design-related research approaches in various disciplines shows that many researchers who are involved in design activities struggle with the question how and what to publish.

We conclude that, for faculty-based projects aiming to deliver digital learning materials in higher education, further articulation of a new design-related research category is desirable. In order to label this approach we suggest the term 'design-oriented' in the sense of oriented towards a design. Such a call for the addition of a new design-related research category does not imply denouncement of one of the emerging research approaches discussed in this article. It just implies that in a faculty-based context the applicability of these approaches is limited.

A main reason to suggest a new design-related research category besides the existing flavors of design-related research is a wish to avoid output requirements that are defined in terms of 'basic primitives' such as 'theories' or 'understanding' insofar these are not defined operationally. In fact, a set of operational definitions of what 'understanding' means in a specific subject matter context, is in our view an output of a research project, rather than an output requirement of a research approach. For design and a design-related research approach, we rather would promote explicit descriptions of interfaces as output requirement. In fact, from a design-oriented view, it is surprising that the concept of interface is only very implicit in ISDSR and does not yet play a role in the contributions to EDR. A second reason to suggest a new design-related research category is related to 'iteration' and formative evaluations. On the one hand, it was illustrated that 'iteration' turns out to cover a wide range of different forms of iteration. On the other hand, 'iteration' and formal formative evaluation results do not appear as outstanding characteristics in publications of typical faculty-based projects aimed to deliver digital learning materials. In absence of an operational definition of 'iterative' and in particular if one allows for informal formative evaluations, one might also question what type of research is not iterative. Thirdly, experience in the FBT projects has shown that articulation of the project goals in terms of operational design requirements consumes a large part of the project resources. These efforts have to be legitimated by the importance of operational design requirements. Indeed, in design or goal-oriented research, defining the goal in terms of operational design requirements is crucial if one wants to demonstrate in a case study that the goal can be achieved (i.e. that a proof of feasibility can be provided). In the methodological literature discussed in this article, output classes such as operational design requirements and a proof of feasibility tend to receive insufficient explicit attention. Fourth, the new design-related research approach should take into account the faculty-specific context, roles, stakeholder concepts, availability of resources, goals and the primary intention to deliver useful innovative digital learning materials.

A final question is how to arrive at an articulation of a new research approach and methodology. Some might prefer to discuss new research approaches and methodologies before actually doing such research. However, at an abstract level, comparisons of design-related research approaches soon become entangled in a maze of interpretations of primitive concepts. Therefore, it might be better to conduct new forms of research and couple methodology development to a discussion of the obtained results and the corresponding publications. This is much the same as the approach followed in (Peffers, et al., 2007) to arrive at a process model for ISDSR. It is a sort of bootstrapping process. In this process, researchers must be willing to take risks in exploring the boundaries of what is - in a specific discipline - considered research. Faculty who invest time, attention and faculty resources in contributions to the 'scholarship of teaching' are likely to do so within a frame of reference of their primary research discipline. The implicit boundaries of valid knowledge production in their discipline may not be the same as those in other disciplines (Patton, 2002), in particular, they may not be the same as in educational research disciplines or in IS research disciplines.

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