Research by Design: Design-Based Research and the Higher Degree Research student

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Abstract

Design-based research lends itself to educational research as the aim of this approach is to develop and refine the design of artefacts, tools and curriculum and to advance existing theory or develop new theories that can support and lead to a deepened understanding of learning. This paper provides an overview of the potential benefits of using a design-based research approach in Higher Degree Research (HDR) in Education. Design-based research is most often associated with conducting research in technology-enhanced learning contexts; however, it has also been used in the broader field of research in education. A review of six theses was undertaken in order to identify how characteristics of a design-based research approach were used in Doctoral dissertations. The results of the review indicate that the use of expert groups, micro-phases, diverse participant groups, and a flexibly adaptive design enabled the researchers to refine and improve their research design and their understanding of the problem.

Keywords

Design-based research, Higher Degree Research, technology and learning, research into doctoral education

Introduction

This paper provides an overview of design-based research and the Higher Degree Research (HDR) experience. While the term *design* conjures a range of frameworks and applications, in the context of this paper it is used in relation to a methodical approach – *design-based research*. In research in the field of the Learning Sciences and technology enhanced learning, the use of design-based research has gained a reputation as being the methodology of choice (Barab, 2006; Barab & Squire, 2004; Edelson, 2002; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; The Design-Based Research Collective, 2003). Design-based research lends itself to the field educational research as its underlying premise is to develop the design of artefacts, technological tools, and curriculum and to further an existing theory or develop new theories in naturalistic settings that can support and lead to an deepened understanding of learning (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007; Barab & Squire, 2004; Fishman, et al., 2004).

In design-based research there is a focus on the design process itself at local level, as Schoenfeld (2009) explains that 'the products of well conducted design experiments are improved interventions *and* improved understandings of the processes that result in their productiveness', which are productive contributions to the research community. The cyclic and iterative processes involved in design-based research are aligned with the authentic design of educational

environments; hence, there is a natural alignment between design research and research in education (Lesh, 2003). In this respect, design-based research is a methodological approach that supports an investigation of a learning design.

An overview of design-based research is provided in this paper and design-based research is discussed in a HDR context. Several theses that have used a design-based research approach are discussed and the strategies used by the HDR students to ensure validity and trustworthiness of the design are also presented.

Overview of design-based research

During the 1960s, design research evolved as a recognised field of study. The first generation of design theories were heavily enmeshed in technical design; however, criticisms of this perspective contributed to viewing design as a problem solving process (Dorst & Dijkhuis, 1995). The view of design as a process of reflection-in-action was a result of constructivist influences on the explanation of design (Dorst & Dijkhuis, 1995). Schön's (1983) constructivist-based proposition of an alternative epistemology of practice, presents design as a reflective conversation with the situation. In this context, problems are actively framed by designers (or researchers, in this case) who make "moves" in improving the perceived current situation or problem. In design research, there are two main paradigms: design as problem solving and design as reflection-in-action.

At this stage, it is necessary to differentiate "design" as a research methodology in education contexts from the process of design. When design is viewed as a kind of research approach, it tends to be done so in a context that values the creation of knowledge (Faste & Faste, 2012). "Design-based research" is a research approach that extends existing methods as a means to address the issue of linking theory and practice in educational research. The coining of the term "design research" in a methodological context is credited to Ann Brown in 1992 (Collins, Joseph, & Bielaczyc, 2004). Brown's (1992) "design research" converged qualitative and quantitative operations, collected multifaceted data and focused on in-depth proving of theory. Wang and Hannafin (2005) note that similar and sometimes interchanged terms such as "design experiments," "design research," "development research," "developmental research" and "formative research" are often grouped with design-based research. While there are differences between the approaches, many of the characteristics are shared. In this paper, the term "design-based research" will be used.

Design-based research is an approach that supports the exploration of educational problems and refining theory and practice by defining a pedagogical outcome and then focusing on how to create a learning environment that supports the outcome (Reeves, Herrington, & Oliver, 2005; Wang & Hannafin, 2005). According to Plomp (2007), design-based research 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 ideas ('the intended' and realisation has been achieved" (p.13).

Design-based research is often defined as a series of approaches rather than a single approach allowing for the flexibility of the research design (Barab & Squire, 2004; The Design-Based Research Collective, 2003). Due, in part, to the adaptability of the design, the approach has been used across a range of educational settings as "one of the main motivations behind design-based research is to make learning research more relevant for classroom practices" (Reimann, 2010, p. 37). Design-based research is often at the convergence of design and theory and the design-based research framework supports traditional outcome-based evaluation and the importance of design (Edelson, 2002). The emphasis is not on refining education practice, but on addressing and dealing with theoretical issues and questions that arise (Collins, et al., 2004). Systematic evaluation of the consecutive research phases or iterations contributes to theory building (Plomp, 2007). The cyclic and iterative processes involved in design-based research are in alignment with the authentic design of learning environments and theory building (Lesh, 2003). As such, design-based research

tends to be adopted by researchers who are conducting studies in authentic educational situations, such as classroom settings in order to generate theory and design relevant to a particular context.

Three fundamental principles of design-based research are:

- addressing complex problems in real contexts in collaboration with practitioners;
- integrating known and hypothetical design principles with technological advances to render plausible solutions to these complex problems; and,
- conducting rigorous and reflective inquiry to test and refine innovative learning environments as well as to define new design principles.

(Reeves, 2006, p. 58)

The emphasis on naturalistic settings supports the development of contextualised, but sharable, theories and cumulative design knowledge in classroom or learning environments. Schoenfeld (2009) states that "properly constructed, a design experiment consists of the creation of an instructional intervention on the basis of a local theory regarding the development of particular understandings" (para. 9). Hence, the goal of using a design-based research approach is to "build a stronger connection between educational research and real world problems" (Amiel & Reeves, 2008, p. 34).

Design-based research lends itself to HDR research as research students place themselves in the role of instructor and researcher and conduct their investigation in an authentic, localised, context. The characteristics of the research design, such as the iterative use of design, evaluation and reflection, the use of expert groups and problem and theory refinement, which can be used by HDR students to develop a more robust research study.

Three phases of a design-based research study

Studies that adopt design-based research tend to have three distinct stages: preliminary research, a prototyping phase and an assessment phase (Plomp, 2007).

In the *preliminary research stage*, a needs and context analysis is undertaken, a review of the extant literature is conducted, and the researcher/s develops a conceptual or theoretical framework for the study. The first phase of a design-based research study is fairly standard in HDR contexts in that research students will develop a proposal based on the articulation of a research problem that is based on a literature review and includes a conceptual or theoretical framework.

During the *second or prototyping phase*, which is the iterative design phase, a number of iterations of the materials and/or approach are undertaken, with each iteration being a micro cycle (micro phase) of the research. Mixed-methods of data collection are used. The combination of data collection strategies allows for a more robust understanding of the learning environment (Bannan-Ritland, 2003; Brown, 1992; Fishman, et al., 2004; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005). Common forms of data include surveys, observations, interviews, logbooks, pre- and post-tests and student products (Barab & Squire, 2004; Ketelhut et al., 2010; Plomp, 2007). Each of these micro cycles is a stand-alone study that may focus on fine-tuning a particular aspect of the study with a formative evaluation being the most important research activity at the conclusion of each phase. The formative evaluation is aimed at improving and refining the materials, approach and theory.

The final stage is the *assessment phase*. The purpose of this phase is to conclude how the outcome of the investigation meets the pre-determined specifications of solving the problem (Plomp, 2007). In this phase, recommendation for future work may be generated.

Cycles of iteration and prototyping phases

It is the second phase of a design-based research approach, that is, the cycles of iteration and prototyping, which warrants further investigation due to the value this stage offers HDR students. For a HDR student, design-based research permits the use of all and any types of data to reach an operative or effective design (Gorard, et al., 2004; Squire, 2004; Wilson, 2004). The focus on iteration is not just to evaluate an innovation, for example, a hardware or software, but rather to produce and refine design principles that can provide guidance for similar research studies or development endeavours (Amiel & Reeves, 2008).

In Figure 1, a model of design-based research illustrates how the iterative cycles which are characteristic of design-based research are part of the process of refining the solutions. In this figure, the traditional predictive research approach is contrasted with the design research approach. The main difference between the two models is that a design-based research approach supports the clarification of the problem and the development of design principles and theory refinement through a cycle of reflection, evaluation and refinement whereas a predictive approach supports hypothesis development and refinement.

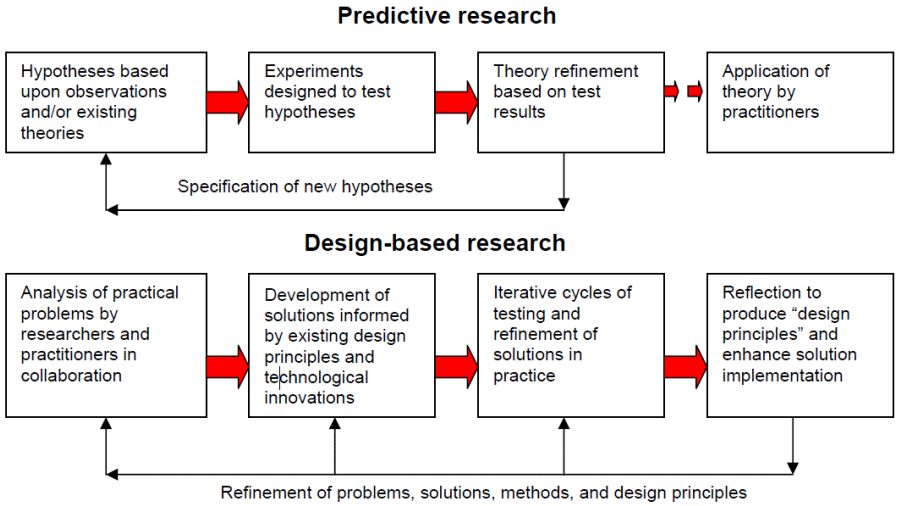

Figure 1. Model of Design-Based Research (Amiel & Reeves, 2008)

According to Amiel and Reeves (2008):

> The development of design principles will undergo a series of testing and refinement cycles. Data is collected systematically in order to re-define the problems, possible solutions, and the principles that might best address them. As data is re-examined and reflected upon, new designs are created and implemented, producing a continuous cycle of design-reflection-design. (p.35)

The reflection on the data gathered in each iteration and the subsequent re-design is aimed at refining the product and theory. As Wang and Hannafin (2005) suggest, in a design-based research study, data are analysed immediately, continuously and retrospectively and that part of this cycle of data collection involves stages, such as a comprehensive literature review coupled with the systematic and purposeful implementation of research methods. This iterative process leads to the development of design principles, which are then reflected upon and evaluated through the refinement of the problem, solutions and methods.

What this means is that a HDR student can systematically use iterative cycles of design to inform subsequent design prior to the final study and assessment phase. This process of refining and redefinition of the design and the achievement of goals contributes to the development or building on of valid theory (Edelson, 2002; Reeves, et al., 2005; Wang & Hannafin, 2005). Waderman's (2005) generic research design model (Figure 2) demonstrates the dual outcomes of design-based research as the practical product and a contribution to theory. Through the cycles of analysis, consultation, development, testing, refinement, reflection and evaluation, the principles and the solution implementation are revised and refined. The nature of design-based research as an educational research approach means that data collection sustained over several research cycles will yield a robust body of data to inform design and theory – it also means that HDR students have the opportunity to revise their research focus which may enable students to move away from a naive understanding to a more nuanced understanding of an educational problem.

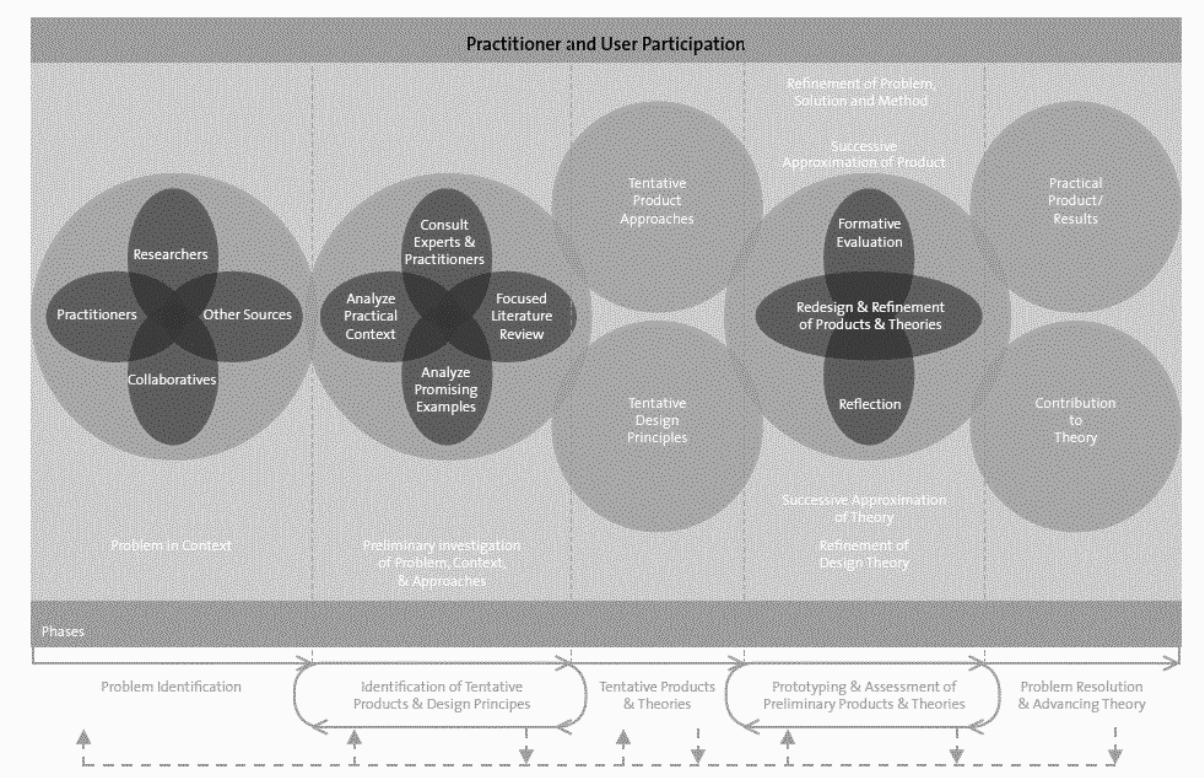

Figure 2. Wademan's (2005) generic research model

Literature search and article selection strategy

An electronic search of articles from educational databases, such as ProQuest, and university Digital Thesis Collections was conducted for theses published between January 2000 and January 2013. Keywords included in the search were: design research, design-based research, education, phases, cycles, and iteration, which are key characteristics of design-based research. In addition, the reference lists of published articles on design-based research were also reviewed to identify potential theses. The thesis title, abstract, literature review and methodology were reviewed to ensure that the study was specific to design-based research in education. Reference lists from each thesis were scanned for relevant references on design-based research. Of the original fifteen theses that were examined, six were retained for the review.

Common characteristics of theses using design-based research

There were several categories for reviewing the theses. Firstly, that the students had clearly articulated that they were using a design research or design-based research approach that was consistent with the definition of the characteristics put forward in the literature. Secondly, that the research study used phases or cycles in the design of the research for refining the artefact or approach and that design was a central element to the research. Thirdly, that the study was undertaken in an education setting. The rationale for these categories was that design needed to underpin the intent of the research so that it was foregrounded in the literature review, the methodological approach and the results. Identifying theses that were all undertaken in education settings meant that it was easier to extract the application of the methodology. That is, all of the studies were aimed at improving an aspect of an educational problem. Table 1 outlines criteria engaged in HDR studies that were embedded into the research design.

Table 1. *Design-based research categories*

Criteria	Description	Examples of criteria in theses
Micro-phases	Series of iterative data collection phases that test and evaluate design. Each cycle in the study is a piece of research in itself	Several tests of materials prior to main field test that examine a different aspect of the design or theory
Expert groups	The inclusion of several expert groups throughout the study to evaluate the materials and data collection instruments	Engage with expert groups, such as key stakeholders, visiting scholars or senior academics to review design. Submit research stages for peer review in conferences
Different participant groups	Test materials with a range of participants groups	Engage groups, such as teachers, pre-service teachers, designers, in the study prior to testing with students. Use different pilot groups to test different prototypes
Flexibly adaptive	Ability to take on several roles without losing sight of the role of researcher	Use of evolutionary planning framework which is responsive to field data and experiences as acceptable moments during the course of a study

In Table 2, a comparison of the PhD studies is presented. Each of these six theses claimed explicitly to have used a design-based research or design research approach. In these theses, several micro phases were conducted and numerous iterations of the original design were undertaken. There was an array of research contexts and timelines for the data collection cycles. In the case of Bower's (2008) research, the iterations were conducted over three university semesters with unit of study cohorts where Bower was the instructor. Whilst in other studies, such as Squire's (2004), there was more opportunistic sampling as the study was conducted in a classroom, afterschool program and a summer vacation program with smaller interventions were Squire was a visiting instructor. The research cycles were given a variety of names, such as iterations, cases, phases and micro-phase; however, the performed the same function and they

were used to refine the research design.

The studies all used mixed-methods of data collection. For example, Kennedy-Clark (2012) and Bower (2008) both used persistent observation and discourse analysis, and Masole (2011) used a baseline study coupled with survey feedback. Other sources of data included reflective journals, pre-and post-tests and semi-structured interviews. The studies drew on expert feedback, in some instances, the feedback was used as checkpoints (Mafumiko, 2006; Masole, 2011), whilst in others, such as Squire's (2004), the input from expert groups and peers was built into the design as a form of moderation.

Table 2. *Comparison of PhD theses using design-based research*

Researcher	Research Area	Iterations	Multi-disciplinary	Data
Mafumiko (2006) Researcher	Design of experimental chemistry curriculum	Prototype phases (used diverse participant groups including high school student, teachers and pre-service teachers; 4 versions of the materials)	Use of expert groups	Mixed-method, pre-tests and post-tests, interviews, surveys, and observations
Squire (2004) Researcher/ instructor	Use of commercial games in secondary education	Cases (used 3 diverse student groups)	Additional researcher and teacher used for observations an data collection and to elicit different interpretations.	Mixed-method, observations logbooks, and student products
Bower (2008) Researcher/ instructor	Use of web-conferencing in higher education	Iterations (same unit of study over 3 semesters)	Peer feedback	Mixed method, persistent observation, reflective journal, and multimodal discourse analysis.
Mor (2010) Researcher/ instructor	Design in technology enhanced mathematics education	Iterations (used 4 iterations including an initial '0' iteration of free forming ideas)	Additional researcher on all instruction activities. Multi-disciplinary team and on-going feedback from peers.	Mixed method, design data, student productions, and observations
Kennedy-Clark (2012) Researcher/ instructor	Use of games for inquiry learning in secondary education and pre-service teacher education	Micro-phases (used 5 diverse participant groups including teachers, pre-service teachers and high school students; several iterations of the materials)	Additional researcher for coding data. Ongoing peer review and feedback processes, and expert groups used.	Mixed-method. Pre- and post-tests, interviews, document analysis, discourse analysis, and persistent observation
Masole (2011) Researcher	Assessment in Agriculture in Botswana schools	Phases (used 2 phases, the first was a baseline survey and the second included 4 prototype phases)	Used expert groups	Mixed-method, Interviews, surveys, and observation

In regards to the choice of data collection strategy, there was consistency in the rationale for the selection. For example, observation and "persistent observation" were used because the researchers explained that they were directly involved in the interventions and, in this, observation provided a rich source of data that could identify subtle shifts in classroom dynamics while persistent observation allows the researcher to identify what is relevant to the study and what is not (Lincoln & Guba, 1985). Through persistent observation, a researcher can also see how students and teachers function, which groups are motivated, which groups struggle, and how the teachers interact with the students. Moreover, logbooks and reflective journals were used to keep a record of the events and the researchers reflections so that changes in options and ideas could be mapped across the study. In the case of studies such as Bower's (2008) and Squire's (2004), persistent observation and the maintaining of logbooks and reflective journals formed a significant part of their data.

The point to be made here is that the research students used multiple forms of data and feedback from experts to build moderation and validity into their studies. On their own, in a one-shot study, each source of data would probably not be of substantial importance to the thesis, but in the case of something like Bower's (2008) reflective journals that were compiled over the course of three iterations of the design a more robust data set is gathered. What design-based research offers HDR students is a research approach that has a mechanism for refinement, reflection and triangulation over a number of phases of research. These micro interventions can use a number of strategies to build reliability and trustworthiness into the design.

Micro phases and prototyping phases

The use of micro phases or prototyping phases in design-based research is a strategy to ensure reliability of the design before the final field work study. As design-based research aims to ascertain if and why a particular intervention works in a certain context, micro research phases provide researchers with an opportunity to refine the design and to gain a more informed understanding of why an invention may (or may not) work in that context (Plomp, 2007). Micro phases involve a series of small scale design studies that result in the subsequent revaluation of the materials before the final product is used in a school-based study. The use of micro phases is part of what Plomp (2007) refers to as the prototyping stage: "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)" (p. 25). Each phase should be presented as a separate study as there may be different research questions, population groups, data samples and methods of data analysis. This approach was used by Mafumiko (2006) (see Table 2), who undertook a micro-scale investigation of improving the chemistry curriculum in Tanzania, and Squire (2004), who conducted three cases in the use of the computer game *Civilization III* with different student groups in different settings in order to refine his design.

Figure 3 shows the progression through Mafumiko's (2006) study and highlights incremental progression through the phases. It is evident that there were four versions of the design prior to the final field test in the school-based study. Here, the design was scrutinised by experts and teachers to improve the materials used in the final study.

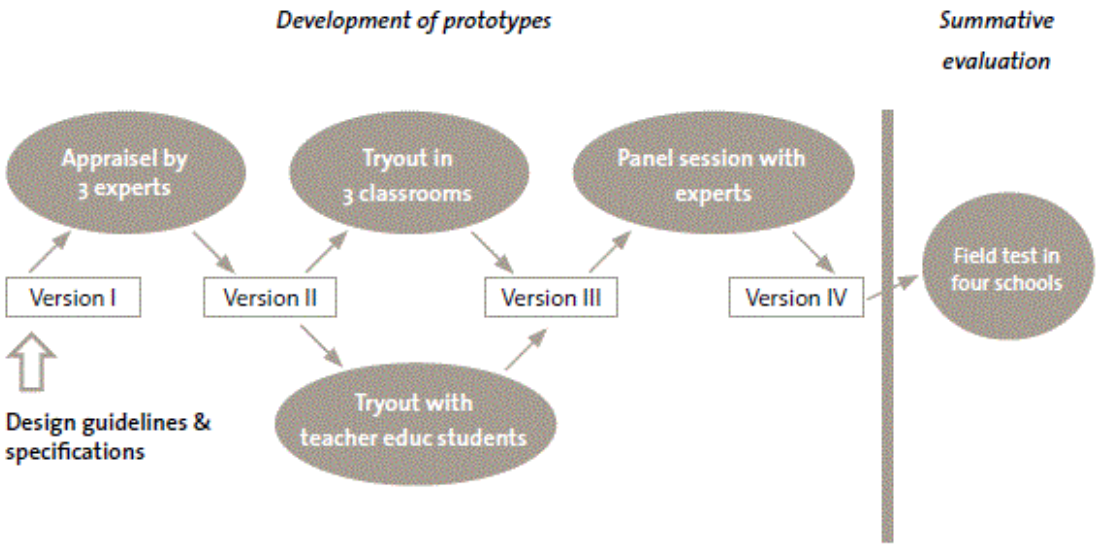

Figure 3. Example of research design showing micro phases adapted from Mafumiko (2006), cited in Plomp (2007)

Masole's (2011) study, in turn, drew on Mafumkio's design. Figure 4 presents a variation of the research design model.

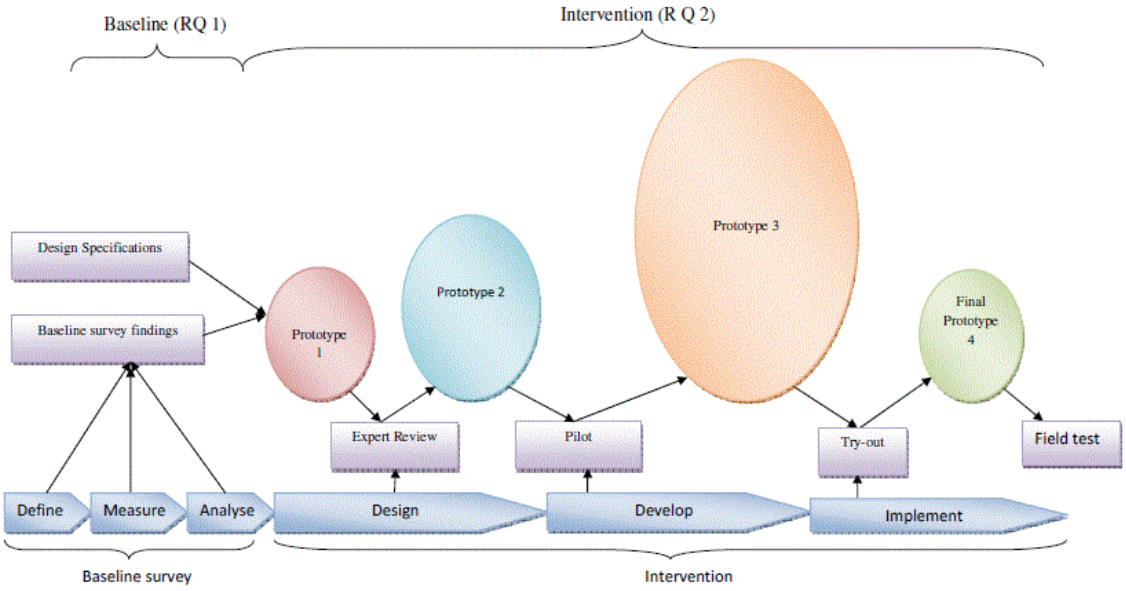

Figure 4.2: *Research design (Source: Adapted and modified from Mafumiko, 2006, p.48)*

Figure 4. Research design showing micro phases adapted from Mafumiko (2006) cited in Masole (2011)

While the aim of the micro phases is not to replicate a preceding phase it can be used to ensure dependability. For example, Masole (2011) used a Design, Measure, Analyse, Design, Develop and Implement (DMADDI) framework. This was spread across the research phases: define, measure, analyse were the first phase, and design, develop and implement were the second phase. The original caption has been left in the figure as it acknowledges Mafumiko's (2006) design. The use of the micro phases can build dependability into a study. According to Shenton (2004), a researcher can establish dependability "if the work were repeated, in the same context, with the same methods and with the same participants, similar results would be obtained" (p. 71). Hence, each stage of the study should be informed by research on similar studies.

In addition, to develop the consistency of the approach, the repetition of the phases is encouraged in investigation of "all reasonable areas" to ensure that early closure does not occur, thus reducing the impact of researcher bias (Lincoln & Guba, 1985). Studies, such as Bower's (2008) built dependability into the research design by being conducted with three similar cohorts over a number of semesters. That is not to say that each cycle was repeated *per se*, but rather the preceding phase was used to inform subsequent designs and the refinement of theory.

Expert groups

One of the issues that can arise in design-based research by a solo investigator, such as a HDR student, is the occurrence of conflicting researcher roles; that of the designer and developer, the facilitator and the evaluator of research. While playing multiple roles can be beneficial in that a researcher can understand the whole process, there are, at times, tensions between the roles. Hence, it is proposed that it is necessary for HDR students to implement checkpoints during the process to ensure that objectivity is maintained. The use of multidisciplinary research teams is seen as a strength of design-based research as a greater breadth of understanding can be brought into the research environment that from solo research or mono-disciplinary studies (Reeves, et al., 2005; Wang & Hannafin, 2005).

HDR students can draw on the benefits of a multidisciplinary team through the inclusion of several expert groups throughout the study to evaluate the materials and data collection instruments (surveys, pre-and post-tests and observation schedules) and interrogate the findings providing a degree of rigour that may otherwise escape a solo researcher. As the designer and developer, solo researchers need to ensure that the instruments and materials are testing what they were meant to test. This process of external review should occur prior to the initial data collection and any school-based field test. Mafumiko (2006), Masole (2011), Kennedy-Clark (2012) and Squire (2004) subjected their designs to the scrutiny of experts. Where possible, the data should be coded by a second researcher. The results should also be submitted as conference papers in a timely manner to maintain objectivity via a blind peer review process. As the designer and developer of the materials, this process of external and internal review maintains the integrity of the research. Overall, Cobb et al. (2003) clarify that the size and type of research teams depend on the purpose of the research and they explain that a modifications to the research design may be necessary in a study wherein the researcher is conducting the teaching sessions.

Diverse participant groups

The use of prototype phases with a range of relevant participant groups is also recommended for two reasons. As Reimann (2010) explained, it is often difficult for ethical and practical reasons to conduct lengthy studies in classroom situations. For ethical reasons, school student populations are difficult to access. School-based studies are also resource-intensive and running ongoing studies with student groups can be difficult for a HDR student, or, in fact, for any researcher. Using a range of participant groups in the prototype phases can mitigate issues of accessibility. For example, Squire (2004) accessed participants in after-school programs as well as classrooms. Masole (2011), Kennedy-Clark (2012) and Mafumiko (2006) used diverse participant groups including teachers, pre-service teachers and school students. Moreover, by accessing a range of relevant participant groups, such as teachers and pre-service teachers, value can be added to a

study as they can identify issues with the design prior to the final field test. By conducting studies with a range of participant groups, the materials can be critically analysed prior to the final field test with a student group.

Flexibly adaptive research design

The nature of design-based research necessitates researcher adaptability. The notion of evolutionary planning is described by McKenney et al. (2006) as a planning framework that is "responsive to field data and experiences as acceptable moments during the course of a study" (p. 84). Adaptability, according to Plomp (2007), can be ensured by the researcher being prepared to take on the role of designer, advisor and facilitator without losing sight of being a researcher. Plomp (2007) also explains that as the research takes place in a real world setting, often the wishes and needs of partners may influence the study. Given that design-based research takes place in a "real world" context and is based on iterative cycles of design and re-design resulting in ongoing changes, it is necessary to implement a planning framework.

Overall, while the examples here are drawn from educational fields, the focus of the studies was diverse including curriculum re-design, science education and maths education. Participant groups ranged from school students to teachers. What is of note is that all of the studies used prototype phases and several iterations to refine the problem and design used in the study.

Conclusions

This paper has focused on design-based research in education; however, there is potential in using a design-based research approach across the disciplines. The three phases of a design-based research study build reliability into the design by enabling checkpoints that support a HDR student in redefining and reflecting on their research as it progresses. It was found in the review of the theses that using design-based research allowed for the realisation of promising small-scale examples of interventions and the generation of methodological guidelines for the design and evaluation of these educational interventions. One benefit raised in the review was that the cycles of iteration and evaluation of the design process might actually reduce the overstating of assertions and conclusions.

The purpose of this paper was not to push design-based research as *the way* of conducting research in HDR contexts; rather, the benefits of this research approach are outlined as means of demonstrating how the use of cycles of iteration and prototype or micro phases can be used to build reliability and trustworthiness into a research study. One final note on design-based research and the criteria presented in this paper is that HDR students often lack the resources to conduct large scale research studies and consequently focus on micro studies which may be more manageable and achievable. This does not reduce or nullify the value of these contributions to the field. However, what it does suggest is that the contributions need to be appreciated on the basis of the trustworthiness of the design and the contributions that these studies make to local educational contexts and theory building. On the whole, the crucial determinant in a solo or team research study is that the individual or team has the expertise and skills to develop the initial design, undertake the experiment and undertake a systematic and retrospective analysis of the data.

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