Chapter 26

Electronic Performance Support for Curriculum Materials Developers: A Design Research Project in Sub-Saharan Africa

Susan McKenney & Thomas Reeves

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26. Electronic performance support for curriculum materials developers: A design research project in sub-Saharan Africa

Susan McKenney & Thomas Reeves

Abstract

Although teacher guides are, next to textbooks, among the most-used teacher resources worldwide, little empirical research has been conducted on how to support the developers of such guides in their complex task. Through a multi-year iterative process of analysis, design, evaluation, and revision, design research was conducted to gain insight into desirable characteristics of an electronic performance support system for curriculum materials developers in southern Africa. From a practical standpoint, this study yielded positive experiences for the participants and a software tool that is not only valid and practical, but also has the potential to positively impact users if implemented well. From a scientific standpoint, design principles were generated, tested and refined for key system characteristics, specifically: content, support and interface. The design study flanking evolution of the tool helped (re)shape each prototype, and to track effects on both the professional learning of the materials developers and the quality of the curriculum materials made. Because long-term, high-quality design studies in the field of education are rare, this chapter focuses on the research approach, and its affordances for contributing to theory-development while also capturing and speaking to the needs of practitioners.

1. Introduction to the problem

In the last few decades, the concept of Teacher Resource Centers (TRCs) has become widely accepted across southern Africa as an essential ingredient of a professional support structure for teachers and schools (Hoppers, 1998). Among other activities, TRCs often provide the context in which resource center staff members collaborate with local teachers to develop lesson materials that exemplify specific elements of an innovative curriculum. In such a context, curriculum development and teacher professional development can be viewed as two mutually enhancing processes. As Jonassen and Reeves (1996) put it, “…the people who seem to learn the most from the systematic design of instructional materials are the designers themselves” (p. 695). This study set out to explore how a computer-based tool might be able to contribute to and even enhance the synergy that exists between curriculum development and professional development at a very natural crossroads… the creation of exemplary lesson materials.

Another goal of this study was to explore how to refine emerging theories that are used to support curriculum development, e.g., collaborative and reflective inquiry (Bray, Lee, Smith, & Yorks, 2000). Educational design research (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) was applied in this study because of its twin focus on practical solutions and theoretical knowledge refinement. Design research studies emphasize the whole cycle of scientific inquiry, often involving sub-studies in cycles throughout the stages of problem identification, hypothesis (re)forming, solution development and testing. Design studies require interaction and collaboration among researchers, teachers, and other stakeholders.
According to Barab and Squire (2004), design research is “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” (p. 2). Design research has been gaining momentum as a distinct genre of educational research over the last two decades. In special issues of highly respected journals, the need for attention to be given to design research was demonstrated: *Educational Researcher* (2003, 31(1)), *Journal of the Learning Sciences* (2004, 13(1)), *Educational Psychologist* (2004, 39(4)). Books devoted to the topic examine design research conceptualization (van den Akker et al., 2006) as well as methodological options (Kelly, Lesh, & Baek, 2008; McKenney & Reeves, 2012; Reinking & Bradley, 2008).

Several different models for design research have appeared in the literature. Some are more conceptual, and have been used to help describe differing sequences of steps in the design research process (cf. Ejersbo et al., 2008). Others emphasize a flexible but clear process, along with varying degrees of conceptual, or substantive, support. Reeves (2006) offered a model that highlights the process but is less detailed from a substantive standpoint; whereas that of McKenney, van den Akker and Nieveen (2006) tends to be more focused on core concepts and less on the process. A model put forth by Bannan-Ritland and Baek (2008) pays attention to both process and concepts, but has not been widely adopted. Based on an analysis of existing models, McKenney and Reeves (2012) produced a multi-phase model that attempts to adequately represent the dynamic nature of design research, while accounting for large degrees of methodological freedom (see Figure 1).

The trapezoid at the top of the model represents the steadily increasing interaction with practice through implementation and spread of the resultant intervention and understanding that emerge from design research. The two dark boxes on the right side of the model illustrate the twin outcomes of design research. The three squares in the model represent the three major phases of inquiry and development which are central to design research. The first phase (left) represents the interactive give-and-take between analysis and exploration, typically seen during the early stage of a design research study. The second box represents the interactive processes of design and construction that yield the prototype interventions which are tested and refined during the third phase: evaluation and reflection. Most design research projects will repeat each of the interactive processes represented both within and across these boxes several times. (Indeed, the study described in this contribution also involved multiple micro-cycles within each main phase of analysis and exploration, design and construction and evaluation and reflection.) In so doing, slight refinements can be made. For example, it is common for the focus of evaluation and reflection to shift as insights and interventions mature. Earlier alpha-style evaluations tend to center on the internal structure of interventions (validity); during beta testing, use in context (practicality) receives more attention; and once interventions stabilize and are used under representative circumstances, more robust gamma testing can take place (effectiveness).
The aforementioned literature on design research have been pivotal in garnering increasing support for a research approach now considered by many scholars to be a viable route to increasing the relevance of educational research. However, legitimate questions about the ultimate value of educational design research have been raised (cf. Anderson & Shattuck, 2012). Clearly, the evidence supporting this approach will be enhanced if the current body of literature contained more in-depth examples of long-term, high-quality design research. More examples demonstrating how this approach can be applied in the context of developing countries would be especially valuable. This paper describes each aspect in the multi-phase model (Figure 1) and illustrates its elements through a 4-year study on supporting curriculum materials developers in southern Africa.

2. Development of conceptual framework

Many tools have been developed to provide support to curriculum developers, but at the time of this study (McKenney, 2001), none were available that specifically targeted the kind of work carried out by teacher-designers working in Teacher Resource Centers (TRCs) in southern Africa. In addition, very little guidance was available in scientific literature that could underpin such work, by giving answers to questions like: What would a scientifically valid tool - one that contained state of the art knowledge and was internally consistent - look like? How could it be made practical for this context? What features would be necessary for it to yield high quality materials and offer learning experiences to the users?

Therefore, the Computer Assisted Curriculum Analysis, Design & Evaluation for Science Education in Africa (Cascade-Sea) program was developed and design research was conducted to address (a) the practical problem of the need for support in TRCs; and (b) develop theoretical understanding that could serve the creation of similar tools. This study was guided by the following main research question: What are the characteristics of a valid and practical support tool that has the potential to impact the performance of (resource) teachers in the creation of exemplary lesson materials for secondary level science and mathematics education in southern Africa? A conceptual model illustrating the relationships between the main concepts in this study are illustrated in Figure 2.
3. Design and development stages

Approach
At the beginning of the study and throughout its evolution, guidance was sought from literature relating to curriculum development, teacher professional development, exemplary materials, existing support structures (such as TRCs) and computer-based performance support. Insights from relevant literature along these thematic lines helped to shape the structure of the study as well as the Cascade-Sea program itself. These ideas were articulated in the form of tenets that served to guide research and development activities. These tenets pertain to the following topics:

- **Local relevance**: any educational innovation must be carefully examined and, if necessary, (re)tailored for the context and culture in which it will be implemented.
- **Collaboration**: design and development activities (related to an innovation) must be conducted in collaboration with and not for those involved.
- **Authenticity**: efforts must be based on a working knowledge of the target setting and, where possible, research and development should be conducted in naturally occurring test beds.
- **Mutual benefit**: a skillful attempt should be made to combine research activities with meaningful experiences for the participants.
- **Continuous (re)analysis**: careful and regular analysis of the risks and benefits of the innovation should be conducted in the light of the target setting, with design and development decisions being taken accordingly.

Three phases
The design study on supporting curriculum materials developers took place in several phases, as shown in the multi-phase model (Figure 1). As described above, the model features three boxes, or phases, in which research activities take place: analysis/exploration, design/construction and evaluation/reflection. The interaction between design/construction and the other phases demonstrate how empirical findings feed into design. In this study, two iterations (also known as micro-cycles of design research) took place in the first phase, four iterations in the second phase, and two in the third phase. Within each iteration, multiple data collection activities took place in which participants cooperated to yield multiple types of data (e.g., by responding in a focus group to a demonstration and then, after a hands-on session, giving feedback through a questionnaire).
Throughout the study, four main strategies were used:
- **Developer screening**: Developers 'walk through' design documents and critically reflect
- **Expert appraisal**: Experts provide feedback e.g., on working prototypes or user products
- **Micro evaluation**: Prototypes are used under near-to-normal circumstances
- **Tryout**: Prototypes are used by the target group in the target setting under natural conditions.

Figure 3 shows the approaches (top of box) main data sources (bottom of box) used in each of the three phases.

![Figure 3: Methods for data collection in each phase of the study](image)

Detailed descriptions of each phase have been reported elsewhere (McKenney, 2001). Toward understanding the research approach, and its affordances for contributing to theory-development while also capturing and speaking to the needs of practitioners, the basic process is briefly described here.

The primary goal of the analysis and exploration phase was to obtain a working knowledge of the target setting, user group and areas in which a support tool may be put to work. Previous design research focused on computer-based support for curriculum developers (Nieveen, 1997) had yielded a tool for formative evaluation that served as a springboard throughout this study, especially in the analysis stage. This phase consisted of two main cycles. Beginning with a study of relevant literature along with interviews with experts and professional curriculum developers, the analysis and exploration phase culminated in visitations to various curriculum development/teacher development programs in southern Africa. During the visitations, an English version of the CASCADE tool (originally developed in Dutch) as well as initial analysis findings were presented to expert and user groups who were involved in materials development as part of an inservice scenario. Members of these groups offered feedback in the form of initial design ideas, as well as tentative suggestions for future cooperative activities.

The design and construction phase relied heavily on the cooperation of both expert and user groups as well as other institutions and individuals. Through iterative cycles of design, development and prototype evaluation, the Cascade-Sea tool evolved. The main criteria upon which these (four) prototypes were evaluated during the design and development phase were validity (state-of-the-art knowledge and internal consistency) and practicality (use in context based on Doyle and Ponder's conceptualization including: instrumentality; congruence with existing beliefs and cost in relation to anticipated benefits).
The evaluation and reflection phase of this study explored the potential impact of the Cascade-Sea system in terms of (potential) contributions to teacher development and curriculum development as a result of its use. This phase may best be described as 'semi-summative' in nature. This is because during this phase evaluative activities mainly possessed characteristics of summative evaluation (in particular, the aim), but maintained a number of formative evaluation elements as well. Results from this phase were used to assess CASCADE-SEA’s effectiveness in terms of its potential to positively impact (a) the performance of its users with regard to the quality of materials they would create; and (b) professional development of its users.

Sampling
The study described in this chapter was primarily conducted through successive evaluation of four computer-based prototypes. Each prototype was evaluated with a number of groups (ranging from two to six different groups per prototype). While chain referral (or snowball) sampling best characterizes the strategy used for making sampling decisions with regard to each individual group, stratified purposeful sampling was used to facilitate comparisons between types of groups. The two types of participants in this study were user groups and expert groups. The user group included preservice teachers (this group became involved as a result of the study's emergent nature and the aforementioned chain referral strategy), inservice teachers (emphasizing resource or facilitator teachers) and curriculum developers. The expert groups consisted of science education experts, curriculum development experts and experts in the area of computer-based performance support. Earlier stages of the study (focused more on understanding validity-related criteria) involved a higher degree of experts than those in later stages, which examined the practicality and potential impact of the Cascade-sea program. In such later stages, user groups played a more prominent role in evaluation activities. In total, 510 participants (see also Table 1, in the following section) contributed to this study.

"Choices of informants, episodes, and interactions are being driven by a conceptual question, not by a concern for 'representativeness.' To get to the construct, we need to see different instances of it, at different places, with different people," (Miles & Huberman, 1994, p. 29). The structure of this study was shaped by the desire to explore many 'different instances' of participant perceptions. As a result, a wide variety of data collection activities was undertaken. Each time a data collection opportunity arose, usually through dialogue with (potential) participants, researcher/developers weighed off perceived costs (time, finances, etc.) with estimated benefits (e.g. depth and validity of prototype feedback), in accordance with the tenets that guided this study. Many activities were eventually conducted even when the perceived benefit was relatively low, because (as long as the related costs were also minimal), this was considered a low-risk method of exploring what types of 'different instances' would actually yield the most fruitful data. This kind of flexibility was built into the study, so that knowledge and findings from previous cycles could then be applied to subsequent ones. Further, consideration of participant suggestions, even with regard to data collection opportunities, was consistent with the relational approach as advocated through the foundational tenets. Table 3.3 in McKenney (2001) reconstructs the researcher's perceptions concerning the salience and the intensity of each micro-cycle for addressing the main research questions. A simplified version is presented here in Table 1, featuring the number of participants in each main cycle and a gradual shift from studying validity, then practicality and then impact potential.
Table 1: Cycle and data weight over time

<table>
<thead>
<tr>
<th>Phase &amp; exploration</th>
<th>Cycle</th>
<th>Validity</th>
<th>Practicality</th>
<th>Impact potential</th>
<th>N Participants*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis &amp;</td>
<td>Literature</td>
<td>SAK</td>
<td>INC</td>
<td>INS</td>
<td>18</td>
</tr>
<tr>
<td>exploration</td>
<td>review</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site visits</td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>Design &amp;</td>
<td>Prototype 1</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prototype 2</td>
<td></td>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Prototype 3</td>
<td></td>
<td></td>
<td></td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Prototype 4</td>
<td></td>
<td></td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Evaluation &amp;</td>
<td>Final</td>
<td></td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>reflection</td>
<td>evaluation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Query</td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
</tbody>
</table>

* Some individuals participated in more than one cycle

Legend

- None = SAK=SAK=state-of-the-art knowledge; INC=internal consistency
- Low = INS=instrumentality; CON=congruency; COS=cost
- Medium = BQM=better quality materials; EPD=enhances professional development
- High

Instrumentation

Instruments were developed to use along with each of the four strategies described above. While variation exists among like kinds of instruments, so do similarities. For example, various interview schemes were designed to gather information about the same aspects (internal consistency of the program interface, for example), while being used in different settings. In such a case, rather than develop completely new instruments, researchers often tailored existing ones. Additionally, instruments were improved wherever possible, based on insights acquired through previous uses. This approach resulted in ‘instrument families’ containing like kinds of instruments with related roots but also certain degrees of variation. As is common in educational design research, a mix of quantitative and qualitative methods was used. Six main families of instruments were used:

- Interview and walkthrough schemes
- Questionnaires
- Discussion guides
- Observation and demonstration schemes
- Logbooks
- Document analysis checklists

Instrument families were typically used with small groups of participants at a time (ranging from 3-12), but the specific procedures used during each of the 34 data collection activities did vary.
Table 2 presents an overview of the 108 times that instruments were administered during this study.

Table 2: Administration of instruments overview

<table>
<thead>
<tr>
<th>Phase</th>
<th>Cycle</th>
<th>Interview &amp; Walkthrough Schemes</th>
<th>Questionnaires</th>
<th>Discussion Guides</th>
<th>Observation &amp; Demo Schemes</th>
<th>Logbooks</th>
<th>Document Analysis Checklists</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;E</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>D&amp;C</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td>19</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>3</td>
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<tr>
<td></td>
<td>4</td>
<td></td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>E&amp;R</td>
<td>4</td>
<td></td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Legend

LR = Literature review and concept validation  
SV = Site visits  
P1 = Prototype 1  
P2 = Prototype 2  
P3 = Prototype 3  
P4 = Prototype 4  
FE = Final evaluation  
Q = Questionnaire  
DG = Discussion guide  
O = Observation scheme  
D = Demonstration guide  
L = Log book  
Qu = Query  
IS = Interview scheme  
W = Walkthrough scheme  
DA = Document analysis checklist

Data analysis

To maximize the potential of the study's emergent design, data analyses were conducted after each data collection activity so as to inform the following ones (and again at the end of the study). Such repeated interim analysis is referred to as 'sequential analysis' by Miles and Huberman (1994) who commented as follows on the strength and weaknesses of this approach: Their "interim analyses strength is their exploratory, summarizing, sense-making character. Their potential weaknesses are superficiality, premature closure, and faulty data. These weaknesses may be avoided through intelligent critique from skeptical colleagues, feeding back into subsequent waves of data collection" (p. 84). In this study, the means used to conduct sequential analyses encouraged such critique.

The processes and techniques used for each data analysis procedure varied along with the nature and scope of the data collection activities (and the resulting yield in data types). Figure 4 displays an overview of the processes and techniques used throughout the study. It shows that both quantitative and qualitative data were collected. Further, it illustrates that analysis of the data was often conducted in cooperation with other individuals such as research assistants and critical friends. Some of the analysis techniques (e.g., case analysis meetings) naturally invited critical friends to help understand (or confirm how to interpret) what was happening. In other instances (wherever considered efficient and effective), the researcher engaged the assistance of one or more colleagues.
What | Who | How
--- | --- | ---
- Quantitative data were collected and used to identify general trends and themes | Data analysis was conducted by the researcher, together (where appropriate) with: | Depending of the type of data collected, one or more of the following techniques were used:
- Qualitative data were collected and used to deepen understanding of trends and themes by examining specific, often more personal insights | Research assistants (n=8) | Translation/transcription
- Qualitative data were collected and used to deepen understanding of trends and themes by examining specific, often more personal insights | Developer group | Summarization of data
- Qualitative data were collected and used to deepen understanding of trends and themes by examining specific, often more personal insights | Critical friends | Calculation of mean, median, mode and standard deviation

Figure 4: Data analysis processes and techniques as applied in this study

To prepare for data analysis, data were translated (where necessary) and then transcribed into text files; and these files were then summarized into separate text files. Depending on the nature of the data, these summaries related to either quantifiable information (mean, median, mode and standard deviation) or qualitative codes (tags or labels for assigning units of meaning to descriptive or inferential information) and patterns (collections of codes identifying emergent themes, configurations or explanations). Please refer to Miles and Huberman (1994) for detailed descriptions of these techniques.

Data were analyzed both deductively (classified according existing schemes) and inductively (through recognition of emergent patterns). The (quantitative and qualitative) data summaries were chunked according to their relationship to the three criteria in the main research question. That is, they were first clustered by criteria (validity, practicality or impact potential) and then by sub-construct (for validity, those were: state-of-the-art knowledge and internal consistency; for practicality those were: instrumentality, congruence and cost; for impact potential those were: better quality materials and enhances professional development). Each summary contained a table with separate sections for content, support and interface issues. Within the tables, each item was color-coded for its relationship to various parts of the Cascade-Sea program or study. These summaries, as well as other interim documents and site visit reports helped to put the data collection activities into perspective. Further, they provided discussion tools for case analysis meetings that took place regularly among the developer group.

In addition to the data analysis techniques mentioned above, the researcher also used photographs, videotapes, developer logbooks and field notebooks during data analysis. Although the instruments described above provided the bulk of the data, revisiting these sources was extremely useful in reconstruction of events, and interpreting data in the proper context. Samples of these sources are shown in Figures 5 and 6. (Please refer to McKenney (2001) for more details.)
Data collected throughout the CASCADE-SEA study were often analyzed twice: immediately after the data collection activities took place (to inform the following decisions), and at the end of the data collection period (to gain an overall perspective). This section discusses the findings, presented according to the three quality aspects investigated. In addition, it describes how these findings contributed to the evolution of the CASCADE-SEA program.

Validity
As described previously, validity pertains to state-of-the-art knowledge (about curriculum development, teacher professional development, computer-based support and how to realize it via the interface), and internal consistency (coherence throughout the various system components). Few participants disputed Cascade-Sea's possession of state-of-the-art knowledge; and similarly, sparse commentary was given concerning internal inconsistencies. In fact, numerous participants were enthusiastic about these aspects of the program. However, the degree to which the program may be labeled valid is much more difficult to pinpoint. For example, while participants generally agreed that Cascade-Sea contains state-of-the-art knowledge, some found the volume to be overwhelming, some were satisfied with it and still others considered it (present but) incomplete. Participant opinions also varied, though not as emphatically, in terms of the internal consistency of the program. Whereas most participants were satisfied with this aspect in relation to the interface and support, opinions diverged with respect to the content of the program. Some participants appreciated the inter-connectedness of the content in the various components, but the majority found this aspect to be (present yet) weak. Although determining where Cascade-Sea's validity should be placed on a quality continuum remains difficult, the participant reactions indicate that the support and interface are subject to less dispute than the content of the program.
Practicality
Practicality refers to the way in which Cascade-Sea fits with contextual realities as well as the individual perceptions and/or beliefs of users in the target setting. This includes the notions of instrumentality (specifying procedures to complete a task); congruence (in this case, linking with the way teachers go about producing exemplary lesson materials in the target setting); and cost (the amount of investment effort compared to the return yielded). Generally speaking, the program was viewed to be practical, and based on the participant responses, ‘quite practical’ might be a better descriptor. Here too, the main area in which opinions diverged was in relation to the content.

With regard to instrumentality, participants generally appreciated the guidance offered by the program; although some concern was expressed (mostly by experts in curriculum development and teacher professional development) that Cascade-Sea could offer too much step-by-step guidance. To some user groups, the level of English used was seen to present an overly difficult challenge. Most participants felt that the program was quite congruent with the needs and wishes of the target group, and many emphasized the importance of using the program within a training setting. Opinions were more mixed with regard to the costs associated with using the program, in particular: time investment. Whereas some participants found Cascade-Sea to shorten the length of time they would otherwise invest, others found the opposite to be true, mostly because the program inspired them to be more thorough than otherwise would be the case. Although suggestions were given for improvements, participants were more consistently satisfied with the support and the interface aspects of the program. And even though their reactions were not always unanimous concerning the degree to which Cascade-Sea may be labeled practical, the overall consensus was far less varied when compared to validity aspects.

Impact potential
In the case of Cascade-Sea, positively impacting the performance of its users means that it helps to create better quality materials than those that would be made without the support of the computer. In addition, the program should contribute to the professional development of its users. The data collected throughout this study indicate that Cascade-Sea does, indeed, possess the potential to positively impact the performance of its users, but that the extent of this potential is strongly influenced by how the system is used and by personal characteristics of those using it.

The structured nature of the program was judged by participants as useful in helping them articulate procedural specifications for the teachers who eventually use the materials. The support and layout of the materials created with the aid of Cascade-Sea were judged to be easy to use and comparable to or better than those created without the aid of the program. Further, participants generally indicated that they felt they learned from the Cascade-Sea experience, although some (mostly experts as well as a few user groups) raised concerns that the program could make things ‘too easy’ for the user and either stifle creativity or encourage ‘laziness’ as a result. Most participants noted that such concerns (as well as the potential benefits) would be influenced by contextual factors affecting implementation.

How findings contributed to fundamental understandings and program development
Because individual influences of research findings on Cascade-Sea’s design would be too numerous to mention, this section contains three tables to illustrate how the research activities contributed to achieving the desired quality characteristics. They are comprised of carefully selected examples from each phase and cycle of activity, related to all three quality aspects (validity, practicality and impact potential) and all three program characteristics (content, support...
and interface). Associated with each attribute introduced in Tables 3-5, a vignette is given that recounts design or revision decisions made, based on participant input. The numbers shown in parentheses correspond to the cells in Table 5.1 of McKenney (2001), which contains the original account of the empirical findings. Though it is not expected that most readers will reference the source table, we offer it here to (a) allow the interested minority to access the empirical reports; and (b) demonstrate transparency in how empirical findings feed design. Each of the tables relates to one of the main criteria sought: validity, practicality and impact potential.

Table 3: Examples of (re)design decisions based on findings related to validity (adapted from McKenney, 2001)

<table>
<thead>
<tr>
<th>Validity</th>
<th>State of the art knowledge</th>
<th>Internally consistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>Curriculum design and development knowledge; related professional development knowledge</td>
<td>Ideas in various components are in line with those in other areas</td>
</tr>
<tr>
<td></td>
<td>Participants evaluating the first prototype (13) recommended the use of concept mapping to help users organize their thoughts on lesson content. This suggestion led to an agreement with the producers of Mindman© to distribute their program with cascade-sea; and to the inclusion of sample concept maps for each topic covered within the program.</td>
<td>During early stages of gathering design ideas (3) and through later versions of product development (17, 19) participants emphasized that the link between the components (and related consequences) not only needed to exist, but should be transparent to users. Toward illustrating how rationale ideas relate to other parts of the program, Kasey's third button (&quot;Tell me the link with my rationale?&quot;) was designed to speak to this need.</td>
</tr>
<tr>
<td>Support</td>
<td>Advice on materials design; Guidance on embedding materials in professional development</td>
<td>Tips, guidelines, templates, advice and help functions are perpetually offered in a consistent fashion</td>
</tr>
<tr>
<td></td>
<td>Participants evaluating both the first and the second prototypes (13, 14) offered suggestions on how to help users improve the quality of their lessons. Such ideas shaped both the overt support offered (e.g., choice menus) in the lesson builder as well as the implicit support given through the structure of the lesson template (summary, preparation, lesson body, conclusion, teacher notes).</td>
<td>Participants recommended (17) that each main phase in the program produce some kind of tangible output that records user decisions, reflects them in another form and offers opportunity for changes, updates or tailoring. Each main component in cascade-sea now features such documents (rationale profile, analysis plan, lesson plans and evaluation plan) as well as guidelines on how and why to customize them.</td>
</tr>
<tr>
<td>Interface</td>
<td>Maximizes the potential of modern ICT facilities</td>
<td>Functions as intended, regularly</td>
</tr>
<tr>
<td></td>
<td>Participants involved in evaluation of prototype two (14) suggested that the database connection be used in other areas of the program, not just for the lesson body. This prompted a complete revision of the 'Idea Book' and the 'Clip Art Gallery' such that they were integrated in a broader database that also contained vocabulary words (and editable definitions) and complete lesson plans. Further, this database was made accessible from the toolbox as well as the design area of the program.</td>
<td>Participants evaluating the third prototype (19) expressed frustrations with data loss. In some cases, this was due to power failures, and in other instances this was because users did not save their work. To relieve the user of this responsibility, an auto-save feature was built into cascade-sea, so that the program automatically records new work in the program every 10 minutes, without any action on behalf of the user.</td>
</tr>
</tbody>
</table>
Table 4: Examples of (re)design decisions based on findings related to practicality

<table>
<thead>
<tr>
<th>Practicality</th>
<th>Congruence</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Guides the user step-by-step in making materials; Offers freedom to work at own pace and in own style</strong></td>
<td>Links up with the needs, wishes and context of the users</td>
<td>Content should include enough of what users need, and not bog them down with unnecessary steps</td>
</tr>
<tr>
<td>Participants suggested (22) that cascade-sea allow the user to indicate when more (and less) support is needed by offering “I don’t know” as possible responses to rationale questions. These options were built in, with the related consequence that cascade-sea makes suggestions for what to do next (in analysis) based on user uncertainties. But these tips remain optional.</td>
<td>Participants emphasized early on (9) and during design activities (26, 27) the importance of incorporating local resources into lesson materials. The ‘Idea Book’ started out as a way to spur on user thinking in this area, and evolved into database contents such as improvisation of equipment and activities that rely on cheap and or local supplies.</td>
<td>Participants recommended (13, 30) that the user maintain the majority of control over what to do and how to do it. Rather than forcing any particular path, regular suggestions from cascade-sea were preferred. (Re)design decisions based on this idea included the simplification of advice given to the user and its presentation (e.g., ✓✓✓ as described in Chapter 4).</td>
</tr>
<tr>
<td><strong>Explains how to use program clearly and concisely</strong></td>
<td>Support is relevant and usable</td>
<td>Support should be extensive, lowering the threshold of investment cost to the user</td>
</tr>
<tr>
<td>Some participants found the level of English used in the program to be challenging (24). One response to this finding was the creation of Kasey’s second button, which offers clarification of difficult words in each area of the program.</td>
<td>During the analysis phase, participants identified (9) the most promising setting for the use of the proposed program: trcs. Throughout design and development, attention has been given to maximizing the potential of a shared resource (e.g. by asynchronous sharing through the database and targeting small teams of designers, not individuals).</td>
<td>Participants especially appreciated the pre-made, editable samples that came along with cascade-sea (30) and requested much more of the same type of support. As a result, ‘canned’ documents were incorporated into each main area of the program (along with recommendations on how to customize them).</td>
</tr>
<tr>
<td><strong>Buttons, navigation and functions are clear</strong></td>
<td>Interface ‘feels’ nice and safe, users are not alienated but motivated to use the program; Operates on technology that is available in the target setting</td>
<td>Interface should reflect the flexibility of the system, in which users determine how they would like to go through the program</td>
</tr>
<tr>
<td>Participants criticized (17, 22, 25) the navigation options (particularly the main panel) in various prototypes. This was revised three times before feedback on the final version confirmed that this aspect was quite clear.</td>
<td>Toward making the program ‘feel’ more inviting, participants recommended the use of more colors and icons (26). These ideas helped shape the current interface design.</td>
<td>Participants appreciated the ease with which they could alter documents (31). To clarify and emphasize this feature and the program’s flexibility (e.g., building lesson inside program with guidance or working independently with the template) additional instructions were added.</td>
</tr>
</tbody>
</table>
Table 5: Examples of (re)design decisions based on findings related to impact potential

<table>
<thead>
<tr>
<th>Impact potential</th>
<th>Enhances the professional development of users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yields better quality materials</td>
<td>The materials that are developed through use of cascade-sea should be valid, practical and effective.</td>
</tr>
<tr>
<td>Content</td>
<td>Cascade-sea should help users to think about materials development in a (more) systematic and thorough fashion.</td>
</tr>
<tr>
<td>Participants suggested (22, 31) that exhaustive use of examples would help users to understand and thereby improve their work. This suggestion was taken and many examples, samples and templates were incorporated into the program. Comments given (55) show that users found these elements valuable, as seen through their explanation of why materials made with cascade-sea are of better quality than those made without the aid of the computer.</td>
<td>Participants offered suggestions (13, 15) pertaining to how cascade-sea might be able to help users generate a clear vision on what they want to do (in terms of making materials) and why. These ideas were incorporated into the rationale component (e.g., by asking users to consider the difficulty level of the subject matter addressed as well as the target teacher's experience, and offering tips accordingly). Participant comments (39, 40) show that these attributes were appreciated and that the process of creating a rationale profile is a valuable learning experience.</td>
</tr>
<tr>
<td>The materials that are created with cascade-sea should contain clear, useful procedural specifications</td>
<td>The materials that are generated with cascade-sea should evidence attention given to form and style.</td>
</tr>
<tr>
<td>Support</td>
<td>Interface helps (teams of) users to visualize the process of materials development and make their work more transparent.</td>
</tr>
<tr>
<td>Suggestive were given as to how cascade-sea can help the user build up a well-structured lesson plan, including step-by-step guidelines. For example, ideas were given (32) as to how cascade-sea could remind the user (of the program) to remind the teacher (using the materials made with this program) to consider ways in which that lesson relates to everyday life. These (and similar) ideas were embedded in the system, and are cited by participants (36, 37) as contributing to more clearly structured lesson plans.</td>
<td>Interface helps (teams of) users to visualize the process of materials development and make their work more transparent.</td>
</tr>
<tr>
<td>Participants suggested that cascade-sea can contribute to user thinking by both explicit prompts (such as posing salient questions [13]) and implicit structuring of tasks (as seen through the procedural and conceptual map offered in the main menu page [3]). These types of cues were appreciated by participants (38) who said that the structure helped their work to be more systematic, and that the program reminded teachers of responsibilities which might not ordinarily be considered.</td>
<td>Early on, participants emphasized the importance of offering subject-specific support (2). In order to provide tailor-made support without the associated risks of rigidity, the cascade-sea program offers generic guidelines, illustrated through subject-specific examples (e.g., sample lesson series goals, concept map templates). Participants found this balance to be a useful start, although the addition of even more (subject-specific) examples was encouraged (56, 58).</td>
</tr>
</tbody>
</table>
The examples of (re)design decisions presented on the previous three pages offer insight into the way(s) in which the research findings contributed to the development of the Cascade-Sea program, and the evolution of the underlying design ideas.

**Design guidelines**

Walker (1990) recommends that shared basis, or ‘platform’ of ideas’ for curriculum development can be extremely useful in helping developers to make the thousands of necessary decisions as they shape their design. The design and development of the Cascade-Sea program was also structured by such a platform, containing ideas of varying degrees of abstraction. As previously mentioned, foundational tenets were formulated in accordance with the overall aims of this study; toward creating the Cascade-Sea tool, the implications (of these tenets) for design were examined. Further, theories and models for curriculum development in general and the creation of exemplary lesson materials in particular were studied to generate development guidelines for creating the program. Finally, by reflecting on the foundational tenets and the development guidelines, together, product specifications for the actual Cascade-Sea tool were elicited.

Each of these layers is described in McKenney (2001) and full presentation is beyond the scope of this chapter. Here, we present a sample from the layer of abstraction that lends itself most to use by other designer/developers: design guidelines. Table 6 summarizes key considerations concerning characteristics of exemplary lesson materials (what Cascade-Sea should help users to create).

**Table 6: Content guidelines for the development of materials in the cascade-sea tool**

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>The users of the material should be able to, at-a-glance, ascertain what the proposed lesson is about in order to decide whether or not it is appropriate for their own use.</td>
<td>Cascade-sea should help the user to create a lesson summary that is both terse and easy to find. Connections to familiar resources, such as textbooks, should be included in such a summary.</td>
</tr>
<tr>
<td>A pre-requisite to a smoothly run lesson (especially in the case of new or innovative practices) is having the necessary materials and equipment on hand at the start of class.</td>
<td>Cascade-sea should (together with the user), generate a list of ways to prepare for the lesson (e.g., pre-mixing of solutions, background information, etc.). As much as possible, Cascade-sea should help the user to create any such supplementary materials (handouts, worksheets, etc.) by offering tools and resources to do so.</td>
</tr>
<tr>
<td>When faced with pressure to squeeze large amounts of content into already packed syllabi, teachers can use recommendations regarding how much time to spend on what kinds of activities.</td>
<td>In addition to realistically planning the time allotments throughout a lesson series, Cascade-sea should encourage materials developers to consider timing for each part of the lesson as well as suggestions on ways to efficiently and effectively conclude a lesson.</td>
</tr>
<tr>
<td>Both the system itself and the materials generated with the aid of Cascade-sea should contain reservoirs of what Ben-Peretz (1975) terms, ‘curriculum potential.’</td>
<td>Cascade-sea should offer materials developers a wide variety of activity ideas (e.g., demonstrations, homework assignments, experiments, group projects, field trips, forms of assessment, etc.) which may be incorporated into the materials and serve as sources of inspiration for the end users.</td>
</tr>
</tbody>
</table>
Table 6: Content guidelines for the development of materials in the cascade-sea tool (continued)

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creators of curriculum (be it materials developers or classroom teachers) are more likely to incorporate outside ideas when they can easily be adapted for one's own context or situation.</td>
<td>Cascade-sea should offer materials components in dynamic, rather than static formats. The program should also encourage its users to do the same. For example, text descriptions of activities should be editable so that the materials developers may tailor them if desired. Also, alternatives, substitutions and improvisations for materials (such as laboratory equipment and supplies) which might be difficult to obtain should also be recommended in the teacher guides.</td>
</tr>
<tr>
<td>Where applicable, content-specific theories of learning in science and mathematics (as opposed to general theories that are applicable across domains) should be incorporated into the materials.</td>
<td>Cascade-sea should assist the user in articulating specific expectations (problematic areas related to that topic, typical misconceptions regarding the content, likely student questions/reactions) so as to better prepare the end user of the materials and thereby lower any potential threat associated with trying out new or innovative activities.</td>
</tr>
<tr>
<td>The design of a message can influence the way it is interpreted and used.</td>
<td>Cascade-sea should encourage materials designers to consider the visual form and style of the teacher guides they create. Further, they should strive for a layout that accommodates the way teachers generally use such lesson materials (laid open on the teacher’s desk for reference during a lesson).</td>
</tr>
<tr>
<td>The materials creation process is often best served by multiple perspectives toward development.</td>
<td>Cascade-sea should provide support and resources for further elaboration and improvement of the materials generated, including development activities that may be carried out without the computer.</td>
</tr>
</tbody>
</table>

**Process guidelines**

The five tenets that molded the foundation of this research also form a useful framework for addressing additional questions concerning ICT-related design research, particularly in developing countries. So, in light of the findings from this study, the foundational tenets are revisited, once more. Based on these ideas, recommendations for continued and related research and development efforts concerning educational applications of ICT in developing countries are given (see Table 7).
Table 7: Considerations for research and development activities pertaining to ICT applications in developing countries.

<table>
<thead>
<tr>
<th>What to consider</th>
<th>Deliberation tips</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Local relevance</strong></td>
<td>Examine the target setting, together with the target group, to determine if the proposed innovation really addresses an expressed need in a culturally and contextually relevant fashion. Consider alternate versions of the innovation that address potential (long or short term) problems.</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
<td>Few, if any participants in innovation, are experts on all types of educational developments. Especially in new and inventive areas involving ICT, people tend to have less experience and therefore may have difficulty in contributing to certain dialogues. Expend effort to determine ways in which all participants can provide input in a fruitful and appropriate fashion.</td>
</tr>
<tr>
<td><strong>Authenticity</strong></td>
<td>All over the world (not only in developing countries), educational change is considered difficult, if not impossible to steer. At most, authorities may hope to shepherd developments in a particular direction. To do so, educational innovations must illustrate how they relate to what is already known and understood. The more genuine the test situation, the more genuine the results will be. It pays off to invest time and energy in seeking out naturally-occurring test-beds for product design, development, evaluation and revision.</td>
</tr>
<tr>
<td><strong>Mutual benefit</strong></td>
<td>Consider the main goals of the innovation and then look for micro-settings in which these things are already taking place (usually in a less explicit fashion). Capitalize on existing efforts toward both gaining additional support for the innovation and improving its overall quality and impact. The reality in developing countries is that most schools are poorly resourced and most teachers are un(der) qualified. If the innovation relies on more educated personnel or better facilities, take it to a logical ‘home’ where this may be found.</td>
</tr>
<tr>
<td><strong>Continuous (re)analysis</strong></td>
<td>ICT is a field subject to rapid and unpredictable change. Particularly where resources are scarce (in developing countries), it is prudent to carefully examine how innovations may be structured for the long term. Take into account the current realities that are part of the ‘bigger picture,’ (e.g., availability of telephone lines or electricity).</td>
</tr>
</tbody>
</table>
5. Reflection

About the research focus
Anzalone (1991) predicted an increased recognition for the importance of sound instructional design in the creation of curriculum materials in developing countries; he further stated that the development of related capacities would undoubtedly be aided by computers. A step in this direction, the Cascade-Sea study has illustrated that the computer does have the potential to support curriculum development and teacher professional development in southern Africa. It has also highlighted the determining role of the context in which it will be used toward realizing that potential. Input from expert and user groups has indicated that this program (and/or a tailored version hereof) may be particularly useful to professional curriculum developers and preservice teachers, in addition to the target user group: facilitator teachers working at TRCs.

About the research process
Educational design research was found to be particularly suitable for the problem that was central to this study. Several contextual factors increased the inherent challenge of designing support for curriculum materials developers, and the limited theoretical and empirical base from which to draw upon rendered it a more daunting endeavor. The design research approach was flexible enough to evolve alongside insights from each cycle, while maintaining focus on the long term goal of the intervention and of producing knowledge that could be valuable to a wider audience than participating designers alone. Besides the fact that there were direct benefits of this approach in terms of improved capacities on the ground, the approach afforded both opportunities, and challenges.

As stated previously, a design research approach was used to gain insight into desirable program characteristics, implementation strategies and the forms of support that would be desirable while also feasible. This design study evidences the characteristics of design research, organized below according to the set offered by Reinking and Bradley (2008):

- **Intervention-centered:** Having a positive impact on (resource) teacher-designers is central to the initiative.
- **Theoretical:** The program development was informed by research findings and theoretical works; it contributes to theory building about supporting curriculum developers in developing countries.
- **Goal-oriented:** This study explores how to support the complex tasks and professional development of (resource) teacher-designers in southern Africa.
- **Adaptive and iterative:** The tool and understandings about feasible implementation scenarios evolved in light of the experiences and research findings.
- **Transformative:** The intervention stimulates new practices in TRCs.
- **Methodologically inclusive and flexible:** Across the cycles, qualitative and quantitative data were collected; data source decisions were influenced by contextual opportunities and constraints.
- **Pragmatic:** Research, development and implementation efforts were driven by the desire to achieve a valid, practical intervention with the potential to have genuine impact on both the quality of materials developed and teacher-designer learning.

This chapter speaks to the need for more examples of useful long-term design research in the field of education in general and (technology-based) support for curriculum developers in particular.
Based on the experience from this and other studies, we remain optimistic about the potential of design research to contribute to scientific understanding through robust research while also informing the development of interventions on the ground. This approach is useful in a range of contexts, where solutions are needed to complex problems.

**Key sources**


**References**


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