Computer-Based Support for Curriculum Designers: A Case of Developmental Research

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

☐ The research described in this article builds on a previous study that began to explore the potential of the computer's supportive role in curriculum development. The previous study was initiated by the Department of Curriculum at the University of Twente together with the Dutch National Institute for Curriculum Development (SLO). It has yielded a computer program called CASCADE: Computer Assisted Curriculum Analysis, Design and Evaluation, concentrating on formative evaluation for the SLO. Evaluation of this program has indicated that such a tool may offer much to the world of curriculum development, particularly with regard to the formative evaluation of classroom materials (Nieveen, 1997). Findings indicate that use of the CASCADE program saved time and improved consistency of formative evaluation plans and activities, while motivating users to carry out evaluations that otherwise might have been omitted. The CASCADE-SEA study uses the previous CASCADE findings, in the forms of both knowledge and product, as a launching pad for continued investigation into computer-supported curriculum development.

The original CASCADE study suggested that additional fruitful applications might lie in contexts outside that of the Dutch SLO, where curriculum materials are also being produced. In the late 1990s, collaboration between the University of Twente and various curriculum reform initiatives in the southern African region grew. The exchange of information, problems, and potential solutions between Dutch and African institutions prompted a line of inquiry: Could the computer possibly offer valuable support to African curriculum developers?

SHAPING THE INQUIRY

Context

Within the latter half of the 20th century, many southern African countries achieved independence. Among other changes, independence has often brought about new curricula, new subject syllabi, and reform of teaching methodologies (such as a call for more learner-centered teaching). Considering that most countries in this region already suffer from a serious shortage of qualified teachers and a severe lack of teaching and learning materials (Caillods, Göttelman-Duret, & Lewin, 1996), the challenges presented by such changes are tremendous. Many curriculum development efforts have been initiated throughout the region to help cope with post-independence transformation. Experts in the area of educational improvement in the third world tend to agree that sustainable development can only happen when investments are made into local human resources (capacity building). This implies that investments are made into the professional development of teachers, teacher educators, and curriculum developers, preferably in coordination with other major change components, such as curriculum redefinition and materials development, reform of the examination system, and improvement of preservice education.

Many countries in this region (Zimbabwe, Tanzania, Namibia, and the Republic of South Africa, to name a few) employ the use of regional resource centers to support professional development of teachers. In most cases, such centers are staffed with specially trained teachers who are responsible for inservice activities. Often, these facilitator teachers coordinate regional projects, including the development of lesson plans and classroom materials. The creation of classroom materials has been deployed to help teachers (a) improve their subject matter knowledge, (b) strengthen their basic teaching skills, and (c) begin to understand and implement more innovative teaching methods. At the same time, sharing the materials among other teachers (regional or national colleagues) can begin to fill a void of resources and assist in implementing the new curriculum. Toward exploration of how the computer might support these processes, the next section addresses the theoretical stimuli behind the investigation.

Conceptual Framework

Three key fields of study fuse to form the foundation of the CASCADE-SEA research endeavor. These are the notions of (a) electronic performance support systems (EPSS), (b) curriculum development, and (c) teacher professional development. In this exploration, the first is seen as a vehicle to enhance the relationship between the two latter themes. Each of these is addressed below.

EPSS

Much of contemporary thinking regarding the computer-based support of myriad task types stems from the field of EPSS. According to Gery (1991, p. 24), the goal of EPSS is "to provide whatever is necessary to generate performance and learning at the moment of need . . . what distinguishes an EPSS from other types of systems or interactive resources is the degree to which it integrates information, tools and methodology for the user." Yet consensus has not been reached on the ideal balance of various elements in support systems. Raybould (1990) distinguished three similar, but different components of EPSS: (a) an advisory system, (b) an information base, and (c) learning experiences. Nieveen's (1997) definition of EPSS included the integration of job aids (including conceptual and procedural information and advice), communication aids, and learning opportunities.

In this study, the notion of electronic performance support is characterized by four main elements: (a) advice, (b) tools, (c) learning opportunities, and (d) communication aids. *Advice* refers to tailor-made guidelines that are offered to the user to help carry out a particular task based on what the system knows about the user's needs and context. In addition, advice also includes more generic tips that could be supportive to the user, which are not necessarily based on specific input. *Tools* in a support system are elements that can assist the user to carry out a certain task. This category includes templates (prestructured forms that the user need only fill in to use), checklists (lists of things to do or consider) and programs (additional software linked or outside of the EPSS that can be accessed to carry out a task). The *learning opportunities* category refers to parts of the system that allow users to extend their existing knowledge. This may relate to procedural or conceptual knowledge, and can be offered explicitly (for example, in the form of a tutorial or a help file) or implicitly throughout the system (for example, by structuring activities in certain ways). Lastly, the *communication aids* category refers to those aspects of the program that facilitate and or stimulate dialogue (written or verbal, real time or asynchronous).

Both advocates of the concept of EPSS and creators of various support systems for curriculum development presume several advantages of providing computer support. For example, effectively designed and implemented support systems have the potential to promote improved task performance, increased knowledge about the task itself, and organizational learning (Gery, 1991; Nieveen & van den Akker, 1996; Stevens & Stevens, 1995).

Curriculum development

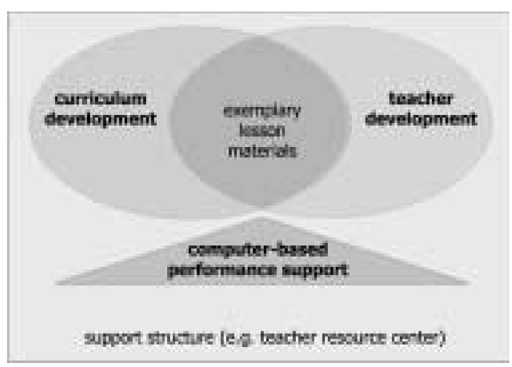
As a field of study, "it is tantalizingly difficult" to know what curriculum is, (Goodlad, 1994, p. 1266). Although Taba's (1962) definition of a *plan for learning* is generally accepted, dispute abounds with regard to further elaboration of the term (Marsh & Willis, 1995). However, it is generally agreed that such a plan at least addresses the aim, content, and organization of that learning (Walker, 1990). Like the notion of curriculum itself, the curriculum development process is multidimensional and complex. As Eisner (1994, p. 371) put it, "The process of curriculum development, like the process of doing quantitative empirical research, appears much neater and much more predictable in textbook versions of curriculum development than it is in practice." Throughout this study, examination of curriculum planning models took place to gain insight on curriculum development processes at two levels: (a) that of the researcher–developer creating a support system, and (b) that of the end user creating teacher guides. In both cases, a fundamental consideration in the development of curriculum is determining who will be involved. In literature, and throughout this investigation, the idea that teachers embrace the role of curriculum maker has been promoted (Clandinin & Connelly, 1992; Eisenhart & Borko, 1991; Lieberman, 1986; Noddings, 1986; Zumwalt, 1988).

Teacher professional development

As previously mentioned, many countries in the southern African region have been facing considerable challenges in designing and implementing curriculum change. Continued professional growth of teachers is widely accepted as an essential ingredient to any educational reform (Black & Atkin, 1996; Fullan, 2001; Loucks-Horsley, Hewson, Love, & Stiles, 1998; van den Akker, 1996; Yager, 1994). So, in view of the stimulating nature of the activities involved in materials production, the creation of classroom resources has been introduced into various inservice programs as a teacher development strategy. The notion of engaging teachers in materials development as an effective form of inservice is widely advocated (Ball & Cohen, 1996; Ben-Peretz, 1990; de Feiter, Vonk & van den Akker, 1995). Simultaneously, this activity fulfills the need in the curriculum development arena for new materials.

The relationships among the main ideas of

Figure 1 ☐ Conceptual model used throughout this study.



this study are illustrated in Figure 1. Here, one can see that the arenas of curriculum development and teacher professional development overlap in the process of creating exemplary lesson materials. Further, the notion of computer-based performance support, designed to assist and enhance that process, is also represented. The final element in the model is the support structure in which these activities take place. This study targeted regional teacher resource centers, although teacher training colleges and universities also served as support structures on occasion. It should be noted that, in this model, the term *support structure* is not limited to physical infrastructure. This concept also includes the larger framework or program (for example, a teacher inservice program) that provides the foundation for such physical and social facilities as teacher resource centers, teacher training colleges, or university faculties.

Aim of the Study

Based on the notion that curriculum development and teacher professional development are two mutually enhancing processes, in this study we set out to explore how the computer might contribute to and even enhance the synergy that exists between them. The computer-based support targeted a very natural crossroads: the creation of exemplary lesson materials. Part of the reason for embarking on a study that explores the potential of the computer to contribute to curriculum development and teacher development in southern Africa is the fact that little has actually been done in this area. Although many studies have examined inservice education, curriculum reform, or even the role of information and communications technology (ICT) in education within this context, few, if any, have looked at the use of performance support toward the creation of exemplary lesson materials. At the same time, research in other settings has confirmed the notion that the arena of computer-supported curriculum development contains great potential to contribute to educational improvement (Nieveen, 1997; Nieveen & Gustafson,1999). The CASCADE-SEA research aimed to generate outputs in the forms of knowledge and product.

Knowledge refers to insight into a systematic approach to the research and development of a tool for the specified purpose. And the *product* is a software program that promotes improved task performance (better quality materials), improved curriculum design and development knowledge (teacher professional development), and organizational learning (among resource teachers).

ABOUT THE TOOL

To better understand the research and development activities presented in this article, the remainder of this section presents a brief description of the resulting product: the CASCADE-SEA program. This software package assists facilitator teachers through important steps in making exemplary, paper-based lesson plans and teacher guides that can then be used by other teachers (usually colleagues in the same region). CASCADE-SEA guides users through the following key steps of curriculum development:

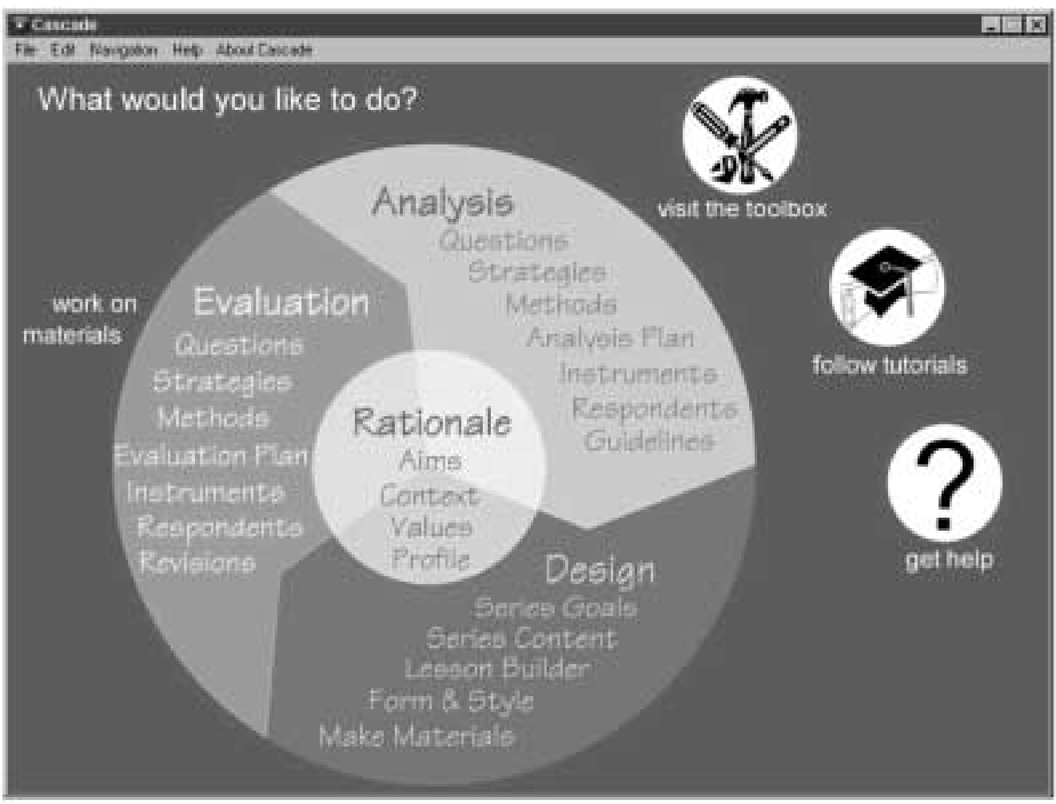
1. *Rationale.* (Why am I making materials? What do I want to achieve with them?)
2. *Analysis.* (What kinds of materials do we need? What are the problem areas?)
3. *Design.* (How can I best structure these materials? What kinds of tips do I include?)
4. *Evaluation.* (Do they work as I had hoped? How can they be improved?)

The CASCADE-SEA program consists of two elements: a Website and a CD-ROM.

Although the number of CASCADE-SEA users with Internet access is rapidly increasing, many still work with the system in an off-line setting. For this reason, the Website is a supplement to (and not a constituent part of) the main program. It supports that to which the Internet is extremely well suited: communication. Whereas the CD-ROM aids the materials designer in making personal decisions about how to create a series of lesson plans (a teacher guide), the Website aims to foster communication between materials designers. This is done through various means, including a discussion forum and a database. The database contains a variety of completed lesson plans, as well as building blocks for materials (clip art, activity ideas, etc.), and is linked with the Gateway to Educational Materials (GEM) consortium (for additional information, visit http://www.thegateway.org/). Visitors are welcome to use what they find, and are also encouraged to contribute resources for biology, chemistry, physics, or mathematics. The site further contains generic support for developing lesson materials and information about the CASCADE-SEA project. For additional information regarding this component, refer to the site itself at: http://projects.edte.utwente.nl/cascade/seasite/ (McKenney, 2001b).

The CASCADE-SEA CD-ROM offers various forms of support throughout the curriculum development process. The program asks users to think about what they would like to achieve (why they are making materials, and what kinds of materials would be useful for that particular setting). If the developer already has a basic rationale in mind, then the program helps to make this explicit and generates a "rationale profile" that may then be used in discussion with codevelopers. Should users have difficulty determining key issues related to the materials to be developed, then CASCADE-SEA will recommend that the analysis section be visited. In the analysis portion of the program, support is offered in conducting a needs and context analysis, which will then aid in forming or reforming a rationale. Once the user has generated sufficient specifications regarding the kinds of materials to be developed, the design phase supports the creation of these materials. It helps the user to map out a lesson series, build individual lessons, and think about the layout of the pages. For users who have completed some of the development (ranging from rationale formation to a complete lesson series), support is also available for conducting a formative evaluation of that which has been designed so far. The evaluation component is heavily based on the origi-

Figure 2 ☐ Main menu page from CASCADE-SEA CD-ROM.



nal CASCADE program, although it has been translated in terms of both language and context. Figure 2 shows the main menu page from the CASCADE-SEA program. It illustrates both the procedural and conceptual model for curriculum development that is supported within this program. Although the model itself (representation and nomenclature) is unique, the ideas behind this model are based on a synthesis of design models described in McKenney, 2001a.

Support is offered throughout the program in all of the formats previously described (advice, tools, learning opportunities, and communication aids). Two examples from each main area are listed here. Tailor-made advice for materials design and implementation is given at the end of the rationale component; this is based on user input selections. Generic tips are given through printable guides that specify how to conduct data collection during analysis and evaluation. Internal tools include data collection instruments that can be used with or without alterations; they come with suggestions for customization. External tools include links to simple drawing, word processing, and mind-mapping programs distributed along with CASACDE-SEA. Implicit learning opportunities are provided through the visual appearance of the main menu and submenus that suggest a structure for the materials development process. The tutorials offer explicit learning opportunities through linear on-screen presentations. Written communication is stimulated by the open source database that allows participants to share work asynchronously, and verbal communication is stimulated through checklists designed to help materials writing teams plan their efforts and allocate tasks within the group.

In addition to the four key steps, four additional features are available: (a) help, (b) tutorials, (c) an interactive agent, and (d) a toolbox containing additional resources (such as the external programs mentioned above). CASCADE-SEA was created using Authorware™ (made by Macromedia) and comes with a user manual in portable document format (PDF). Because of the detailed nature of the program (including approximately 250 different activity screens), a comprehensive portrayal of the system would be inappropriate here. However, additional information is available at: http://projects.edte.utwente.nl/cascade/seastudy/. Hereafter, this URL will be referred to simply as the research Website.

RESEARCH DESIGN

Insights from relevant literature on curriculum development, teacher professional development, exemplary materials, existing support structures (such as teacher resource centers), and computer-based performance support shaped both the CASCADE-SEA program and the structure of the study. Some of these ideas were articulated in the form of tenets that served to guide research and development activities; they pertain to the following topics:

1. *Local relevance:* Any educational innovation must be carefully examined and, if necessary, tailored or retailored for the context and culture in which it will be implemented.
2. *Collaboration:* Design and development activities related to an innovation must be conducted in collaboration with and not for those involved.
3. *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.
4. *Mutual benefit:* A skillful attempt should be made to combine research activities with meaningful experiences for the participants.
5. *Continuous analysis:* Careful and regular analysis and reanalysis 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.

Main Research Question

The research was further guided by the following main question: What are the characteristics of a valid and practical support tool that has the potential to affect the performance of (resource) teachers in the creation of exemplary lesson materials for secondary-level science and mathematics education in southern Africa? This study featured research and development activities that generated successive approximations of a support tool for the given context. The quality of the tool was evaluated in terms of three criteria: (a) validity, (b) practicality, and (c) impact potential; these criteria were carefully defined.

Validity refers to state-of-the-art knowledge offered in an internally consistent fashion. In the CASCADE-SEA tool, such knowledge relates specifically to curriculum development and teacher development, and to contemporary thinking on how to support these processes. *Internal consistency* means that the content, support, and interface elements should be aligned throughout the various system components. *Practicality* relates to the way a tool "fits" with and contributes to the target setting. Elaboration of this aspect has been inspired by Doyle and Ponder's (1978) "practicality ethic," which highlights three important concepts: (a) The notion of instrumentality ("depicting real-world contingencies") relates to the necessity to provide procedural specifications for implementing the creation of exemplary curriculum materials in an actual setting. (b) Congruence (a match between proposed and prevailing conditions) refers to a fit with the way teachers usually conduct curriculum development activities and teacher perceptions of the origins of the proposed innovation. (c) The cost:benefit ratio is calculated in terms of the time, effort, and financial resources that must be invested in order to gain returns in time, effort, satisfaction, learning, and recognition. Because this study focused on the design and development (but not the full implementation) of a computer-supported curriculum development tool, no attempt was made to obtain conclusive evidence in terms of overall system effectiveness. However, researchers were keen on learning about the *impact potential* a system like this might have, if implemented on a full scale. Toward that end, indicators of impact potential were identified in terms of successfully yielding better quality materials, as compared to those materials developed without the aid of CASCADE-SEA, and offering a contribution to enhancing the professional development of the user.

Research Approach

Once the criteria for quality were established, their implications for program characteristics were taken into consideration. Three traits were defined: (a) the program's content, (b) the support offered to the user, and (c) the technical interface. Consideration of how to gauge quality in each of three traits yielded a set of quality aspects, presented in Figure 3. During design activities, these aspects helped developers maintain focus; during research activities, they provided a framework for product evaluations.

Toward learning more about the characteristics of a tool that meets the desired criteria within the context of science education in southern Africa, a developmental research approach was employed. *Developmental research* has been defined as "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness," (Seels & Richey, 1994). For additional information on developmental research, see Richey and Nelson (1996), van den Akker (1999), or Reeves (2000). This approach was selected because of the opportunities it yields in terms of devoting attention to dynamic and complex educational realities, in line with the aforementioned tenets. For example, because of the limited availability of guidelines for developing such tools, evaluation of successive approximations of the desired tool was conducted to help reduce uncertainties in design decision making. This also allowed for the much-needed continuous interaction with experts and practitioners in a variety of settings. The research approach in this study may be more specifically labeled as formative research, since it involved the actual design and formative evaluation of a program.

Three Main Phases

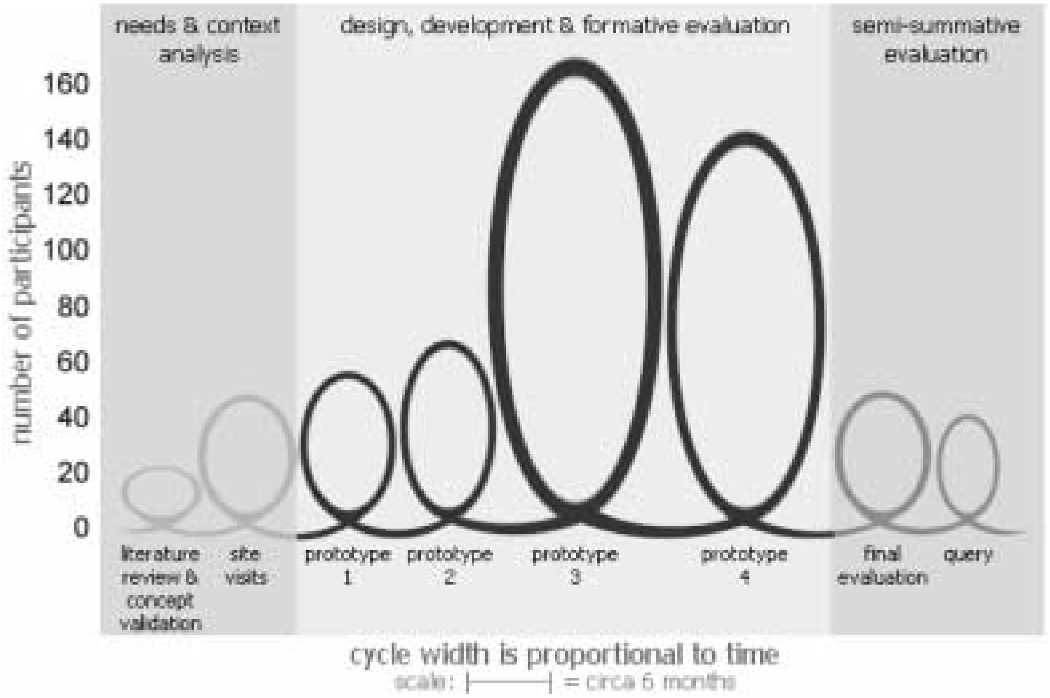
Within this study, three main phases may be distinguished: (a) needs-context analysis; (b) design-formative evaluation of prototype tools; and (c) a more summative assessment of the final product (including exploration of its value for other contexts). The main aim of the analysis

Figure 3 ☐ Quality aspects for designing, developing and evaluating the CASCADE-SEA program.

	Quality \ Traits	Content	Support	Interface
Validity	*State of the art knowledge*	Curriculum design and development knowledge; Related professional development knowledge	Advice on materials design; Guidance on embedding materials in professional development	Maximizes the potential of modern ICT facilities
	Internally consistent	Ideas in various components are in line with those in other areas	Tips, guidelines, templates, advice and help functions are perpetually offered in a consistent fashion	Functions as intended, regularly
Practicality	*Instrument-ality*	Guides the user step-by-step in making materials; Offers freedom to work at own pace and in own style	Explains how to use program clearly and concisely	Buttons, navigation and functions are clear
	Congruence	Links up with the needs, wishes and context of the users	Support is relevant and usable	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
	Cost	Content should include enough of what users need, and not bog them down with unnecessary steps	Support should be extensive, lowering the threshold of investment cost to the user	Interface should reflect the flexibility of the system, in which users determine how they would like to go through the program (maximum degree of freedom, minimum allowance for error)
Impact Potential	*Yields better quality materials*	The materials that are developed through use of CASCADE-SEA should be valid, practical and effective	The materials that are created with CASCADE-SEA should contain clear, useful procedural specifications	The materials that are generated with CASCADE-SEA should evidence attention given to form and style
	Enhances the professional development of users	CASCADE-SEA should help users to think about materials development in a (more) systematic and thorough fashion	Teaches users where resources can be found (inside the program), and how they may be used and/or adapted for own setting	Interface helps (teams of) users to visualize the process of materials development and make their work more transparent

phase was to better understand the needs and context in which the proposed computer-based tool for curriculum development could be put to use. This was achieved through literature study and site visits. The second phase featured the design, development and formative evaluation of four prototypes. The evaluation phase explored the potential impact of the CASCADE-SEA tool in terms of contributions to teacher development and curriculum development resulting from system use. Additionally, an explorative query was conducted of other con-

Figure 4 ☐ Display of the CASCADE-SEA study.



texts and situations in which this tool, or a revised version hereof, might be useful. Figure 4 displays these three main phases as well as the scope of the eight cycles that took place within the phases in terms of participants involved and time spent.

Instruments

In total, 108 instruments were used in this study. Although variation exists among like kinds of instruments, so do similarities. For example, various interview schemes were designed to gather information about the same aspects (e.g., internal consistency of the program interface), 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 has resulted in "instrument families" containing like kinds of instruments, with related roots but also certain degrees of variation. All instruments were based on the framework of quality aspects displayed in Figure 3.

Six main families of instruments were distinguished: (a) interview and walk-through schemes; (b) questionnaires; (c) discussion guides; (d) observation and demonstration schemes; (e) logbooks; and (f) document analysis checklists. The 10 interview schemes contained mixtures of opened and closed questions and were used with participants not associated with the development process. Four of the 5 walk-through schemes were designed for use with members of the development team (1 was used with an expert group, in a slightly different fashion). These walk-through schemes contained screen shots or design specifications and served as discussion tools during screening activities. Whereas most of the instruments were designed to collect qualitative data, the majority of the 38 questionnaires also gathered quantitative data. The questionnaires contained open and closed questions, using various formats including short answers, essays, concept mapping, multiple choice questions, chart completion and Likert scales. The 21 discussion guides contained general questions that helped gently shape group talks, most of which were primarily open and informal in nature. The 7 demonstration schemes were similar to the discussion guides, except that they contained questions asked during interactive demonstration sessions, which made them usually more specific. In contrast to the other instruments, the 14 observation schemes captured researcher perceptions of participant experiences during hands-on sessions with CASCADE-SEA in microevaluations and tryouts. The formats of this type did vary somewhat, and may be sorted into three categories: (a) Those mainly used to help interpret and confirm data from other sources within a circuit consisted of global questions that helped structure researcher reflections; (b) those mainly used to reconstruct the overall atmosphere and experience took the form of a running summary; and (c) those used to portray particular aspects of the hands-on experience contained frameworks into which observation data were placed. Five logbooks were used to capture participant reflections in brief, prestructured format. The 8 document analysis checklists contained open questions pertaining to the quality of either the CASCADE-SEA tool or the materials developed through its use.

Data Collection

Across the three phases of research, four basic strategies were used: (a) screening, (b) expert appraisal, (c) microevaluation, and (d) tryout (cf. Nieveen, 1997). Screenings were conducted by the developers and involved a comparison of that which has been developed and the desired quality aspects. In the expert appraisals, experts were solicited for feedback on products developed, which ranged from global design ideas to working prototypes. The microevaluation strategy was used to evaluate prototypes with small groups of users or experts, outside of the intended setting. Finally, a tryout meant that the prototype be tested by the target group in the target setting. Participants in the four strategies belonged to user groups (preservice teachers, inservice teachers, or curriculum developers) and/or expert groups (science education, curriculum development, or computer-based performance support experts).

In line with the five tenets influencing the structure of the study, the research activities that took place were selected and carried out based on deliberation between the researchers and participating organizations. Such collaboration was considered to be the most effective way of assuring that the research setting remain authentic as well as relevant and beneficial to the respondents involved. In settings where repeated data collection took place (such as South Africa, Tanzania and Zimbabwe) this also afforded opportunities to learn jointly from experience and revise plans and approaches accordingly.

Each time one of the four strategies was used, a data collection "circuit" was completed. A total of 34 circuits took place: 7 during the needs and context analysis; 23 during design and development; and 4 during the final evaluation. The scope of circuits varied. For example, circuits ranged from half-day to month-long events, involved 3–54 people and used one to eight instruments. Data collection took place during workshops, meetings, and interactive presentations, most of which were connected to ongoing professional development activities. Such events were held at teacher resource centers, teacher training colleges, universities, curriculum development institutes, and conferences. The following text describes a typical circuit, while Figure 5 offers an overview of which strategies were used during the 33 circuits that comprised the three main phases of the study.

Example circuit (14 in Figure 5). This try-out took place in cooperation with individuals associated with the Tanzanian Teacher Education Assistance in Mathematics and Science (TEAMS) program, which is based in the Faculty of Education at the University of Dar es Salaam. The second prototype was tested out during a week-long writer's workshop sponsored by the TEAMS project. At this workshop, teachers who had been hand selected (by their peers) as being particularly motivated and competent, traveled to Dar es Salaam from all over the country with the

Figure 5 ☐ Research activities overview.

Phase	Cycle	Circuit	Strategy				Participants						#
							Users			Experts			
			DS	EA	ME	TO	PS	IS	CD	SE	CD	PS	
Needs and context analysis	Literature review & concept validation	1		■						■	■	■	5
		2		■						■	■	■	5
		3		■						■	■		3
		4			■					■	■		5
	Site visits (discussion tool)	5		■						■	■	■	24
		6			■		■		■	■	■		27
		7		■						■	■		3
Design, development and formative evaluation of prototypes	Prototype 1	8	■							■	■	■	4
		9		■							■	■	15
		10		■						■	■	■	19
		11		■							■	■	12
	Prototype 2	12	■							■	■	■	4
		13			■		■		■	■			25
		14				■		■	■	■	■		34
	Prototype 3	15	■							■	■	■	4
		16		■						■	■		12
		17		■							■		3
		18		■				■	■	■	■		10
		19			■			■	■	■	■		33
		20			■		■	■	■	■	■		18
		21			■		■		■		■		19
		22			■			■					18
		23			■			■					30
		24		■						■	■		22
	Prototype 4	25	■							■	■	■	4
		26		■						■	■		11
		27				■		■	■				11
		28				■		■	■	■	■		44
		29			■		■	■					54
		30				■		■	■				16
Semi-summative evaluation	Final evaluation	31				■		■	■				19
		32		■						■	■	■	17
		33				■		■	■				9
	Query	34			■		■	■	■	■	■	■	34
Totals:			4	14	10	6	6	13	13	23	26	12	573
Estimated total respondents when corrected for those who participated more than once:													510

Legend ▒ = Strategies used; ■ = Types of respondents
Strategies: DS=developer screening; EA=expert appraisal; ME=micro-evaluation; TO=tryout
Users: PS=preservice teachers; IS=inservice teachers; CD=curriculum development;
Experts: SE=science education; CD=curriculum development; PS=performance support

goal of creating lesson materials. Throughout the week, groups of teachers worked to create lesson materials that could be photocopied and shared among the regions. A demonstration of the CASCADE-SEA program was given to all the teachers (n = 34) and everyone was encouraged to try it out during the week. Three workstations were set up in the workshop rooms, and assistance was available at all times. Teachers, in small groups and individually, took time to become acquainted with the tool. Comments and feedback were captured through a questionnaire distributed at the end of the workshop. Additionally, data were collected through discussions with TEAMS staff members and participants were observed using the program. Finally the teacher guides created with CASCADE-SEA were analyzed and compared to those made without aid of the program.

Data Analysis

The data collected from each circuit were analyzed and classified according to relevance to either quality criteria (validity, practicality, and impact potential), additional related data, or other nonrelated data. Thereafter, quality-related data were further classified in terms of the domains previously presented: for validity, these were state-of-the-art knowledge and internal consistency; for practicality, these were instrumentality, congruency, and cost; for impact potential, these were better quality materials and enhancing professional development. Next, data were classified according to the quality aspects. As described in Figure 3, these aspects related to program content, support, and technical interface.

Each time a data collection opportunity arose, 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 anticipated benefit was fairly low, because (as long as the related costs were also minimal) this was considered a low-risk method of exploring what situations would actually yield fruitful data. To track this aspect of the research process, each circuit was also evaluated for the weight of its data. The data weight of each circuit was rated twice: The first rating represented the researcher's perceptions before the start of each circuit, and the second rating illustrated the researcher's perceptions after each activity was conducted. As presumed, some activities that appeared less likely to yield significant findings turned out to offer more than foreseen; the opposite is also true. The data weights were based on the researcher's interpretation of the salience and intensity of the data, not particularly on the volume.

A separate summary was created for data relating to each domain addressed in each circuit (not all circuits addressed all domains). Every summary included a brief description of that circuit's activities, the data sources used in that circuit, the sources used for that particular domain summary, data weight before activities were conducted, and the data weight after the activities took place. The data weights were reflected through grey-scale shading, indicating those with no, low, medium, and high contributions. Further, the summaries were color coded (better visibility in the electronic version) as follows: teal text relates to the rationale component; dark green text relates to the analysis component; blue text relates to the design component; pink text relates to the evaluation component; dark red text indicates that the data pertain to more than one area of the program simultaneously or to other parts of the system (not the core components); and grey text relates to issues outside of the program. Figure 6 shows an excerpt from a typical summary; it contains data relating to state-of-the-art knowledge collected during Circuit 14. A total of 187 data summaries were created. These documents are available electronically (PDF) at the research Website.

RESEARCH PHASE DESCRIPTIONS

This section features global descriptions of the research activities undertaken in each phase, outlining the participants, strategies, and instruments used during the various cycles (cycles were represented as loops in Figure 4). The main findings and implications from each phase, which stem from a synthesis of the above-mentioned data summaries, are also presented. Detailed information about each individual circuit may be found in McKenney 2001a, also available in PDF at the research Website (McKenney, 2001c).

Phase 1: Analysis

Main purpose. The primary goal of the analysis 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. As described earlier, previous exploration into computer-based support for curriculum developers yielded a tool (CASCADE) that served as a springboard throughout this study, especially in

Figure 6 ☐ Sample data summary: State-of-the-art knowledge from Circuit 14.

Data Summary: SAK14

Circuit sketch
In this week-long writers workshop, 25 respondents tried out the second prototype

Data Weight

Before	After
M	H

Data used to compile this summary
Dots indicate sources used (out of all sources for this circuit):

- Q-TEAMS3
- DG-TEAMS3

DA-TEAMS3
O-TEAMS3

Data sorted by quality criteria

Content: *Curriculum design and development knowledge*

- The program should ask for the exact grade level of the students (mentioned 5 times)
- More sub-topics need to be added when designing a lesson plan, such as: questions for developing student notes, homework questions and teachers notes
- Connect to learner previous experiences/knowledge at the beginning of the lesson, give problems to the learners to help them understand that concept
- In the introduction, ask local environment questions and technical questions. Have questions lead up to the lesson body. Think about the main aim of questioning at the beginning of the lesson
- Look at Berlutti (Science for 4-16) and more VSO books for ideas
- See Nufield for examples of questioning categories

Content: *Related Professional Development knowledge*

- This program encourages both teachers and students to learn more and expands their knowledge and using computers
- This program demands a lot of thinking
- This program demands or a lot of preparation - good questions to get the appropriate answers

Support: *Advice on materials design*

- Elaborate timing
- Participants indicated the demonstration showed that this program can be very useful and helpful to teachers in simplifying lesson preparation
- The program is easy to use as the teacher just fills in the facts in the plan format

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the analysis stage. This phase consisted of two main cycles. Data were collected especially pertaining to system validity, with tentative ideas about practicality.

Methods. The needs and context analysis phase began with a cycle of literature review and concept validation activities. The concept validation cycle was composed of four data collection circuits, with participants from the Netherlands, Lesotho, Tanzania, and Zimbabwe. The site visit cycle was composed of three circuits, with visits to South Africa, Botswana, and Tanzania. During the expert appraisals and microevaluations carried out within this phase, an English version of the original CASCADE program served as a discussion tool. Initial findings during the concept validation cycle were presented to expert and potential user groups during the site visits. They offered feedback in the form of design ideas and suggestions for cooperative activities during the design and development phase. These ideas pertained to the validity and practicality of the proposed system, especially in terms of which knowledge would be most relevant to include. In total, 18 science education, curriculum development, and/or performance support specialists took part in the concept validation cycle. Their input was gathered through one discussion guide and three demonstration schemes. Thereafter, 54 participants in the site visit cycle (primarily experts, but also some users) shared their insights via seven instruments: two interview schemes, three questionnaires, and two discussion guides.

Findings and implications. Data collected during this phase, together with the simultaneous literature review, contributed to the following major insights in terms of the validity of CASCADE-

SEA. Namely, the program should (a) capitalize on strengths of the existing (original CASCADE) system, particularly in terms of offering a clear, consistent structure and exportable examples, samples, and tools; (b) offer subject-specific as well as generic support for the process of designing lesson materials (particularly teacher materials); and (c) be integratable in science and mathematics education professional development programs throughout the southern African region.

With regard to the practicality of CASCADE-SEA, data from this phase indicated that the program should (a) exploit and perhaps elaborate the advantages of the existing CASCADE program, with particular regard to the step-by-step guidance that increases instrumentality and lowers the cost threshold; (b) specifically target facilitator teachers working in resource centers, often sharing computers and jointly creating exemplary lesson materials; and (c) operate within a Windows™ environment, and assume only basic computer literacy among its users.

Phase 2: Design and Development

Main purpose. The main aim of the design and development phase was to create and evaluate successive approximations of the desired system. Through four iterative cycles of design, development, and prototype evaluation, the CASCADE-SEA tool evolved. The main criteria upon which the four prototypes were evaluated during the design and development phase were validity and practicality, although the greatest emphasis was placed on practicality.

Methods. During the first of the four cycles, Prototype One was evaluated through 4 data collection circuits, with participants from the Netherlands as well as from three universities in the United States. Altogether, 50 participants were engaged in the 3 expert appraisals and 1 developer screening that constituted this cycle. Their input was gathered through 2 walk-through schemes, 1 interview scheme, 1 discussion guide, and 1 demonstration scheme. Prototype Two underwent 3 separate evaluations, which took place in the Netherlands, Zimbabwe, and Tanzania. These activities involved a total of 63 people. Each took part in either a developer screening (n = 4), a micro-evaluation (n = 25), or a tryout (n = 34). Data were collected via 6 instruments: (a) 1 walk-through scheme, (b) 1 questionnaire, (c) 1 discussion guide, (d) 1 observation scheme, (e) 1 document analysis checklist, and (f) 1 demonstration scheme. The third prototype cycle was composed of 10 data collection circuits, with participants from the Netherlands, Swaziland, South Africa, Zimbabwe, Tanzania, and Namibia. Prototype Three was used in 1 developer screening, 4 expert appraisals, and 5 micro-evaluations throughout the 10 circuits that involved 169 individuals, most of whom belonged to either preservice, inservice or curriculum developer user groups. A total of 43 related instruments was used: 1 walk-through scheme, 4 interview schemes, 19 questionnaires, 5 discussion guides, 3 demonstration schemes, 5 observation schemes, 3 logbooks, and 3 document analysis checklists. Prototype Four was evaluated during 6 circuits, with activities in the Netherlands, Namibia, South Africa, and Zimbabwe, with 140 participants. Here too, a blend of users and experts was involved, although users composed the majority. During the 1 developer screening, 1 expert appraisal, 1 microevaluation, and 3 tryouts, data were collected via 25 instruments: 1 walk-through scheme, 3 interview schemes, 10 questionnaires, 4 discussion guides, 5 observation schemes, 1 logbook, and 1 document analysis checklist.

Findings and implications. Throughout the evolution of the various prototypes, formative evaluation data informed development of the program as well as elaboration of ideas on what the program should actually aim to do. For example, determining exactly how users' core ideas (i.e., their rationales for making materials) should be tied into the ideas in other areas of the program was a topic that evolved throughout this phase. The rationale component started out in Prototype One as mostly an organizational area primarily addressing general in formation about a materials development project, and grew to be both visually and operatively the hub of the program in Prototype Four. Further, earlier notions about possibly making CASCADE-SEA into an "expert" system were eventually discarded in lieu of developing a program that, in addition to supporting the complex task of curriculum development, also strives to contribute to its user's professional development. For example, the decision was made to endeavor to make the process of curriculum development transparent and even inviting. This meant that being able to generate materials quickly and easily was not an exclusive priority. Explaining to interested users why certain processes are recommended and how they might be carried out also became important. Facilitating user learning about the complex process of curriculum development was supported by illustrating how and why decisions in one area of the program influenced advice given in other areas of the program.

With regard to maximizing the potential of state-of-the-art of ICT, a number of opportunities existed. Yet deciding how to take advantage of them (if at all) was linked to practical matters. For example, initial concern was expressed as to whether or not users would feel comfortable sharing their work. Latter evaluations showed that participants greatly appreciated the opportunity to share with colleagues, even asynchronously. This insight led to the question of whether or not (and to what extent) CASCADE-SEA should be available via the Internet. And, in turn, this led to further questions such as: Should additional resources be incorporated to facilitate sharing through this medium? And what about including information pertaining to those individuals who contribute, so that teachers may contact them if they desire additional information? Emerging questions such as these demonstrate just how connected the aspects of validity and practicality can be when conducting developmental research. The following section examines other issues that may have started out as what-to-address questions and eventually evolved into how-to-do-that discussions.

Throughout the evolution of the various prototypes, insight was gained toward optimizing the practicality of the program. Formative evaluation data improved understanding about ways to structure the program, how the program could or should be used, and enhancements from a technical standpoint. In terms of the structure of the program, the visual representation had an impact on user interpretation and understanding with regard to the curriculum development process. This was accomplished not only by presenting steps to carry out (e.g., main menu), but also by encouraging users to indicate when they were not prepared to perform certain tasks.

Because of repeated participant requests, the user group was extended to include preservice teachers during formative evaluation activities (although not in development efforts). This gave rise to the realization that CASCADE-SEA might be useful to both preservice teachers and facilitator teachers engaged in professional development activities. But whether used with preservice or inservice teachers, the usefulness of the program would, in part, be determined by its availability. That is, the limited access of users to computers must be addressed for training to make sense. Obviously, computer availability is a prerequisite for initial workshops to take place. But after that, participants must still be able to access the program regularly and often if it is to offer any added value. Another insight with regard to extending the CASCADE-SEA user group stems from the way it is structured. From the very first prototype, participants clamored about the importance of examples. Decisions on how to incorporate examples into the program were linked to perceptions regarding CASCADE-SEA's validity. Namely, opinions were mixed with regard to whether or not to include subject matter support. At the same time, it seemed as though, when it came to examples, more was always better. Further, those examples should be as close to the user's own field of expertise as possible. Hence, the decision was made to structure the program with generic rather than subject-specific guidelines and advice, but to offer subject-specific examples as often as possible. Those few participants involved in formative evaluation activities who did not benefit from the relevant content-based examples, still made use of the generic support. They also recommended that, by adding more examples, the program (and thus the user group) could be extended to other grade levels and other subject areas.

Insights related to technical and interface aspects pertained primarily to screen design and offering users extensive opportunities for support through additional software. Although certain zones were distinguished in the interface starting with the first prototype (navigation, instructions, interaction, etc.), the practicality of the interface design improved as a result of formative evaluation feedback. For example, on-screen instructions were further divided into procedural and content-related information. Improved understanding with regard to what CASCADE-SEA should actually aim to do (generated mostly through validity-related data) served to sharpen ideas on where CASCADE-SEA should 'leave off' in terms of offering support. This, in turn, made it easier to judge what types of external programs would be useful additions to the CASCADE-SEA suite.

Data collected during the design phase showed that CASCADE-SEA does have the potential to positively affect user performance, but it should be noted that this aspect is difficult to measure through the relatively short-term (one week or less) activities that were undertaken during these circuits. Participants judged most of the materials produced with CASCADE-SEA to be of equal or better quality than those produced without the computer. They did, however, comment that the materials could be improved by offering additional support to teachers in terms of describing what learners should be doing during lessons (as opposed to mostly providing guidelines for what the teacher should do). In addition, the vast majority of participants shared the opinion that CASCADE-SEA has the potential to contribute to the professional development of its users. However, most participants involved during the design phase had little previous exposure to any form of computer-supported curriculum development. Without any similar experience for comparison, it may have been difficult for these individuals to imagine what CASCADE-SEA could be missing, or how it might be improved. One the other hand, participants were quite able to comment on the overall quality of the workshops in which CASCADE-SEA was used. Although no great surprise, these results imply that the ability of CASCADE-SEA to contribute to professional development is partially dependent on the way in which it is implemented.

Phase 3: Semisummative evaluation

Main purpose. Because the end evaluation was primarily summative in nature but did maintain a number of formative evaluation elements, the term *semisummative* is used. Although the final phase did consider validity and practicality issues, the main aim of the semisummative evaluation was to determine whether the system created possessed the potential to affect the performance of its users. Particular attention was given to the quality of materials developed with the aid of the system when compared to materials developed without computer-based support. Further, the professional development of users resulting from interaction with the program was also examined. This phase additionally touched on generating ideas for continuing this line of inquiry in the future, and explored potential uses for CASCADE-SEA outside the realm of the original intentions.

Methods. The semisummative evaluation was composed of two cycles: (a) a final evaluation (three circuits) and (b) an exploratory query (one circuit). Data were collected during this phase through a full-day expert appraisal, a week-long microevaluation and a month-long tryout. The three final evaluation circuits involved 45 participants, from the Netherlands, Tanzania, and Namibia. Their responses were captured via 14 instruments: 4 questionnaires; 3 discussion guides; 3 observation schemes; 1 logbook; and 3 document analysis checklists. The query was conducted with two goals in mind. To a lesser extent, this activity contributed to (a) answering the main research question; but the foremost aim was (b) exploring options for follow-up research. The query circuit received input from 34 interested parties from North America, Europe, Africa, and Asia, whose ideas were gathered through one questionnaire.

Findings and implications. All of the users and most of the experts were enthusiastic about the validity of the program. However, the degree to which the program may be labeled valid is much more difficult to pinpoint. For example, participants encountered state-of-the-art knowledge inside CASCADE-SEA, as evidenced by their classification of the program as systematic, comprehensive, rich, clear, thought-provoking, and logical. But aspects listed as strengths by some were considered by others to be weaknesses. For example, the enormous amount of information contained in the program was applauded by the users and the majority of experts, yet a few experts were concerned that CASCADE-SEA could be overwhelming and confusing. Further, a few experts from the field of curriculum expressed concern about the fact that CASCADE-SEA offers only one curriculum design and development paradigm. One even stated that CASCADE-SEA does not reflect state-of-the-art knowledge in the curriculum domain, because in her opinion, it was "not constructivist." Additionally, a few science education experts in Circuit 32 questioned the validity of selected subject matter content. Participant opinions also varied, though not as emphatically, in terms of the internal consistency of the program. Whereas nearly all 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 interconnectedness of the content in the various components, but the majority found this aspect to be present yet weak. Although determining where the validity of CASCADE-SEA should be placed on a quality continuum remains difficult, the participant reactions indicate that validity of the support and interface are subject to less dispute than the validity of the program content.

The semisummative evaluation of the practicality of CASCADE-SEA yielded a number of observations about instrumentality, congruence, and cost. Generally speaking, the program was viewed to be quite practical. With regard to instrumentality, participants generally appreciated the guidance offered by the program, although some concern was expressed (mostly by experts in curriculum de velopment and teacher professional development) that CASCADE-SEA could offer too much step-by-step guidance. Whereas most participants expressed satisfaction in terms of the pace with which they could use the system, there were concerns that the computer's advice would be over-bearing. To a few users and even fewer experts, the level of English was seen to present an overly difficult challenge. Most participants felt that the program was congruent with the needs and wishes of the target group, and many emphasized the importance of using the program within a training setting. For example, 16 out of the 19 participants in Circuit 31 indicated that they would be interested in using CASCADE-SEA in future workshops. Opinions were more mixed with regard to the costs associated with using the program, in particular, time investment. About half of the participants found that CASCADE-SEA shortened the length of time they would otherwise invest, whereas the other half indicated the opposite to be true, primarily because the program inspired them to be more thorough than otherwise would be the case. Although suggestions were given for improvements, more participants were consistently satisfied with the practicality of the support and the interface. And even though their reactions were not always unanimous concerning the degree to which CASCADE-SEA could be labeled practical, the overall consensus on practicality was more consistent when compared to validity.

The data collected during this phase yielded the overall conclusion that CASCADE-SEA does possess the potential to have a positive impact on the performance of its users, but that potential is strongly influenced by how the system is implemented and personal characteristics of those using it. The vast majority of participants felt that using CASCADE-SEA could help users to create better quality materials than they would on their own. The structured nature of the program was seen to help participants articulate (in the form of procedural specifications) useful guidelines for the materials user; the layout of the materials created with CASCADE-SEA was judged easy to use. Expanding the examples (particularly in the database) is one area in which improvement was repeatedly recommended. With regard to enhancing the professional development of users, most participants emphasized that the potential does exist, although a few (mostly experts, as well as a few users) raised concerns that the program could make things too easy for the user and either stifle creativity or encourage laziness as a result. The value of the program as a learning tool for preservice or inservice education was not disputed. But participants from both user and expert groups emphasized that impact potential (on the quality of the materials created and the learning that takes place) strongly depends on how the system is used.

The final research cycle gathered ideas for future uses of the CASCADE-SEA tool (or an altered version). While 24 of 29 query participants indicated that they would be interested in using CASCADE-SEA in their own settings, only half of them thought that implementing the program into their current infrastructure would be feasible. Participants would (like to) use the program in a variety of ways, much broader than those intended by the developers. The most frequently cited uses were:

- As a practice tool to teach computer literacy.
- For macrolevel curriculum development.
- As an example of interactive educational media.
- As a model and/or tool for classroom action research.
- As an example of how curriculum improvement can be approached in developing countries.
- As originally intended, for creation of exemplary lesson materials.

DISCUSSION

Reflections on the findings

Quality criteria. Much of the data collected related to multiple quality criteria (validity, practicality, and impact potential) simultaneously. However, during analysis, data were classified into only one area according to the most, but not the only, relevant relationship to the aforementioned criteria. A number of merits and faults may be associated with the decision to try to sharpen distinctions that are, naturally, more blurred.

Decomposition of the notion of quality was seen as a route to being able to articulate its essence. So, when the quality criteria domains were examined in light of the content, support, and interface traits, the resulting quality aspects (indicated in Figure 3) helped to shape an image of the desired system. Further, the quality criteria helped in terms of understanding the data collected. In particular, they helped to clarify and highlight emergent patterns. In this sense, the quality criteria served their purpose.

However, reflection on the findings shows that they might have served their purpose too well. That is, careful study of how those desired aspects would actually take shape revealed that, in a few ways, they were in competition with each other. Take, for example, program content. When it comes to making decisions about the curriculum design and development knowledge that should be included in CASCADE-SEA, a number of aims were pitted against each other:

- Toward state-of-the-art knowledge (validity), curriculum design and development knowledge should be included, but the question of how much state-of-the-art knowledge is left over to practicality, which says:
- Toward optimizing user cost (practicality), the program should include enough of what the users need and not bog them down with unnecessary steps, but:
- Toward supporting professional development (impact potential), the program should help users to think about materials development in a more systematic and thorough fashion.

Depending on the user's perspective, offering content that stimulates the user to be more thorough than usual could alternatively be experienced as food for thought or as too much unnecessary information.

It appears that conflicts such as these are inherent in the structure of the quality aspects, as they were defined in this study. However, it would be unfair to say that the ramifications of their friction were thoroughly understood at the time the investigation (and in particular, the main research question) was conceived. As these implications emerged, they served as perpetual reminders to weigh available options carefully before making the unavoidable trade-off decisions.

Determining the validity, practicality, and impact potential of CASCADE-SEA was not as tidy as trying to answer a yes–no question. Understanding the program's quality really pertains less to a black or white issue and more to assessing where, on a grey scale, the program should be located. But such a location is in flux, depending on which quality aspects are being inspected, and which ones are given priority. Moreover, these issues are dependent on who is looking to carry out what tasks under which circumstances. As a result, these are reflections of personal value judgments, more than indications of any objective facts. During evaluation activities, participants gave their opinions on the differing quality criteria separately. For example, they rarely reflected on validity issues influencing practicality ones and, as one would expect, they usually evaluated the program against the backdrop of their own, individual, needs and interests.

Target context. To design a good quality system for a particular setting, a working knowledge of that setting is needed, as well as an understanding of what good quality is for that situation. The previous section examined the notion of quality as addressed in this study. This section continues the discussion with a look at contextual factors that influenced trade-off decisions. For each program trait (content, support, and interface) judgments had to be made when it came to prioritizing state-of-the-art (a validity issue) versus state-of-practice in the target context (a practicality issue).

For example, in terms of program content, CASCADE-SEA does not explicitly address constructivism, which could be an important validity aspect for some people. But, some experts argue that radical constructivism (in the short term) can actually do a disservice to African education (Taylor, 2000). They cite a combination of factors to be the cause, such as disputed ramifications and benefits of this approach and debate on how to implement its methods, and its reliance on a well-educated teaching force (cf. Sanders, 1999). The choice to build CASCADE-SEA as a teaching and learning methods "agnostic" was predicated on the supposition that it should speak to the highly varied needs of the majority, not the specialized preferences of the few.

In addition to influencing program content, contextual factors also shaped the way support was designed inside the system. In particular, it was designed for integration into a professional development program, not to be used in isolation. For example, a number of participants lamented the fact that CASCADE-SEA allowed users too much freedom, but others were concerned that the computer had too much control over the materials development process. In terms of being able to make a valuable contribution to professional development, CASCADE-SEA supports users during curriculum development processes, not through prescription but by stimulating deliberate consideration. Hence, support offered inside the tool was designed to encourage reflection and group discussion (in person, not only via the computer). Opting for a program that relies on the local insights of those using it in a professional development setting (as opposed to a self-guided application) was based on a belief that this would, ultimately, be more appropriate and effective for the target context. Given that participant perceptions are an influential ingredient in program impact (Guskey, 2000), such an approach seemed to be worthwhile, because it allowed for tailor-made use (i.e., integration into existing frameworks), and it stimulated would-be users to consider how to maximize the potential benefits of the program within their own settings.

In terms of the program's interface and technical complexion, numerous clashes between state-of-the-art and state-of-practice are obvious, given the fact that technological infrastructure is notoriously weak in developing countries. For example, the poor or out-dated facilities available at many resource centers provided a sound argument for building a technically "lite" version of CASCADE-SEA. On the other hand, the realization that the final version of the program was to be ready a full four years after the research was initiated provided an argument to consider state-of-the-art now versus anticipated state-of-practice in four years. This allowed for more technically demanding aspects to be included than otherwise might have been advisable. Still, certain options (such as an Internet-dependent version, as opposed to the resulting Internet-supplemented one) were ruled out because of contextual constraints. Even in settings where infrastructure is not a barrier, experts have found that, when it comes to EPSS, the fact that something is within the realm of possibilities does not guarantee its feasibility in practice (Miller, 1997). In terms of the interface and technical aspects of CASCADE-SEA, various types of factors (infrastructure, know-how, etc.) within the target context instigated continuous Can it be done? . . . Should it be done? deliberation during design and development activities.

In this study, some elements of practicality actually turned out to be prerequisites to determining aspects of validity. For example, decision-making regarding state-of-the-art curriculum development knowledge (a validity issue) to be integrated into the system was strongly influenced by understanding of target user perceptions and habits (a practicality issue). This is contrary to the assumption made at the beginning of the research that practicality could best be studied after validity issues were clarified. This assumption steered a shift in emphasis from validity to practicality to impact potential during data collection activities. Fortunately, however, the methods used allowed for compensation in this area, as the integrated nature of prototypes (and the evaluation thereof) emphasized assessment of the system as a whole. In fact, because validity and practicality were assessed simultaneously, this process highlighted areas of discord by bringing potential conflicts between them to the forefront of discussions.

Revisiting the Research Approach

A developmental research approach was used throughout this study because of the opportunities it offers in terms of devoting attention to the uncertainties and complexities of educational realities. Although the overall benefits of this approach are perceived to have outweighed the risks, thoughtful contemplation of the execution of this study would not be complete without discussing the enduring struggle between the challenges and opportunities presented by it. Three main points are addressed in this regard: (a) multiple roles played by the main researcher; (b) dilemmas associated with authentic research settings; and (c) the emergent (adaptive) design of the study.

Many roles. The study was both challenged and enriched by the fact that the main researcher was (simultaneously) also the designer, developer, programmer, and (in most cases) evaluator of the CASCADE-SEA program. Further, it was the same individual who (usually) served as the facilitator of workshops and activities in which participants became acquainted with the software. This conscious decision to take on multiple roles was based primarily on the perceived benefits associated with a constant overview of developments and their implications. For example, a constant overview of the various aspects of the study (research history, future directions, developer intentions, etc.) allowed the researcher–evaluator to network toward additional testing situations during field work. Additionally, the practicality and impact potential of the CASCADE-SEA tool was improved by helping the developer to understand the context better. This was even the case in situations where direct prototype feedback was minimal, noncommittal, or for other reasons weak, which would have rendered the findings less relevant from the evaluator standpoint, and might otherwise have gone unused.

Another decision that helped to maximize the potential benefits of multiple roles was the selection of a friendly, easy-to-learn environment for developing the software. The front-end investment in training the researcher to use Macromedia's Authorware™ programming environment (and having a programming coach on call) paid off by allowing for truly rapid prototyping to take place, both in the researcher's mind and electronically. One of the most substantial contributions this decision yielded pertains to problem solving in designing the CASCADE-SEA program. Generally speaking, software developers are acutely more aware of technical options available than are typical educational designers, so much so in fact, that a great deal of their tacit knowledge often remains inaccessible to other members of a development team. This was certainly the case at the start of the CASCADE-SEA endeavor. Nevertheless, by schooling the researcher–designer in how (and why) certain technical aspects are structured, ideas for support were approached creatively, from the various perspectives. Further, these ideas were able to evolve quicker and more appropriately by actually creating, testing, and revising them immediately, with the input of the multiple roles.

Cognizant of the threats to the study associated with the decision to place the main researcher in so many roles simultaneously, two main precautions were taken to mitigate them: (a) vigilant segregation of data and subjective inferences; and (b) triangulation. Recording impressions through photographs, audio- and videotapes, developer logbooks, and field notebooks helped to interpret the data, but these sources were not interspersed with the data. Additionally, three forms of triangulation were achieved: data, method, and investigator. Varying the sources of data (time acquired, locations of activities, and people involved) yielded multiple opportunities to examine similar phenomena. This mitigated the threat of introducing random errors due to drawing premature conclusions based on unique instances. Differing methods of data collection (e.g., through interviews, observations) resulted in data summaries whose sources had been analyzed and then cross-checked, to validate the findings. Where possible, data analysis and interpretation were conducted together with other individuals (research assistants, developer group, and critical friends), to reduce the threat of personal bias. This also reduced the chance of systematic error.

Real-world research settings bring real-world complications. The research approach used in the CASCADE-SEA study allowed data collection activities to take place in cooperation with naturally occurring test beds. The benefits of conducting parts of the study in authentic settings seem obvious: The more genuine the research situation, the more genuine the research results will be. To be sure, these benefits outweigh the risks when it comes to investigations such as this one. However, deeper understandings come at the potential cost of losing control over data collection rigor. When researcher interests are no longer the only ones at stake, compromise is imminent.

For example, participants in earlier circuits learned about the CASCADE-SEA program, and raised the issue of exploring the potential role of this program in preservice education. Adding preservice teachers and associated counterparts to the sample group resulted in the collection of unanticipated types of information that turned out to be quite useful. However "population validity" (cf. Bracht & Glass, 1968) was consequently threatened. Given the fact that generalization to a particular population or situation was not a high priority, and that deeper contextual understanding was considered more valuable, this seemed an acceptable concession. Nonetheless, it does typify the kinds of dilemmas faced by those who prioritize the mutual benefit of research activities (for researchers and participants). At the same time, it emphasizes the need for researcher–participant creativity in the selection of activities that meet the needs of all parties in volved.

In addition, real-world investigation venues also place certain limitations. Particularly when a "cultural stranger" (cf. Choksi & Dyer, 1997 in Thijs, 1999) attempts to carry out research in a foreign setting (as was the case with most circuits of data collection activity), the degree to which an outsider can conduct meaningful research must be addressed. In many situations, participants are hesitant to be completely open with researchers from different cultural contexts. Toward earning participant trust and building an understanding of the context, the importance of collaboration and mutually beneficial activities cannot be over emphasized; these are the two main avenues available to a researcher who prioritizes the insider perspective. This is not to say that being an outsider is completely without advantages. In some situations, it actually allows for a degree of objectivity and, along with that, a freedom (or forgiveness) for honesty that is not permitted to those within a particular group.

Adaptability. The adaptability built into the approach used throughout this study has offered many possibilities for understanding and dealing with the myriad complexities inherent to the nature of the CASCADE-SEA investigation. While developmental research offers many benefits and opportunities, such an emergent approach also demands that attention be given to the resulting consequences in terms of how a study is designed, as Smith indicated:

> Whether emergent programs are more developmental, driven by the attainment of programmatic goals, or more adaptive, responsive to certain pressures forcing programmatic change, they are characterized by rapid, often dramatic, changes which make the creation and implementation of stable evaluation designs very difficult. Successfully evaluating such programs requires a certain degree of flexibility in the design and conduct of the evaluation study. (1990, p. 209)

Within the framework of a systematic approach, this study incorporated the necessary and sufficient conditions for enabling the reflective processes that fed its evolution.

The flexibility provided by multiple perspectives allowed fortuitous data collection opportunities to be utilized. Even though the structure of data collection activities was subject (if not open) to local influences, the basic sequence of exploring validity, practicality, and impact potential remained the same. Not only was this adaptability valuable because of the additional data that were collected, it also proved insightful in terms of learning about what additional kinds of data collection opportunities could be useful. For example, researcher expectations regarding the salience and intensity of some data collection activities were quite low, especially in such noncommittal settings as brief (half-day) demonstrations or discussions. But by having the flexibility to try them out some of these activities proved to be much more useful than anticipated. Although rarely sufficient to stand alone without the input of longer term, hands-on participant experience, data collected in these sessions often served a confirmative purpose highlighting emerging patterns in the findings. Similarly, these types of sessions often informed one perspective (hat) better than another. And finally, because priority was given to the quality of the feedback (as opposed to the quantity), even brief sessions allowed particularly insightful individuals to share their ideas.

Circuit 26 was notably illustrative in this regard. It was entirely unplanned (it took place while the researcher was in Namibia for another purpose) and seemed, at the start, to have more potential toward public relations than toward the collection of useful data. However, the discussion that took place during that two-hour seminar turned out to be one of the deepest, most insightful sessions in the entire study. While it yielded relatively little data in terms of detailed prototype feedback (making this circuit less relevant for the evaluator hat), this circuit contributed significantly to the evolving conceptualization of what the program should (and should not) aim to do and why, thus being quite relevant from the developer viewpoint.

Conclusions

The CASCADE-SEA study was designed to explore the potential of the computer to support science and mathematics education materials developers in southern Africa. Through the development of a valid and practical system, this study has shown that the computer does have the potential to positively affect curriculum development and teacher development by supporting the creation of exemplary lesson materials in the aforementioned context. Users generally produce better materials than they otherwise would, and learn from this process because of the program's combination of the following traits:

Content: CASCADE-SEA systematically structures the materials development process and illustrates its iterative nature through analysis, design, and evaluation activities that are guided by an explicit rationale.

Support: CASCADE-SEA blends generic and tailor-made advice, internal and external tools, implicit and explicit learning opportunities, and written and verbal communication aids to assist the user throughout the materials creation process.

Interface: CASCADE-SEA offers the content and support through a direct, consistent, and forgiving visual and technical representation, which grants the user both flexibility and control over the process.

This study has produced both substantive and procedural outputs (cf. van den Akker, 1999). Substantive outputs include the CASCADE-SEA program itself, as well as design principles pertaining to the characteristics of the tool; procedural outputs include insights on a systematic approach to the research and development of a tool for the specified purpose. The tool was described, in brief, at the beginning of this article. The design principles, which were not previously addressed in this article because of length restrictions, are briefly described here. They have been articulated on three levels of abstraction: (a) foundational tenets, (b) development guidelines, and (c) product specifications. As mentioned in the section on Research Design, foundational tenets were formulated in accordance with the overall aims of this study. The same themes also influenced the design of the program. These relate to the issues of local relevance, collaboration, authenticity of the research setting, intensifying the synergy that should exist between curriculum development and teacher development, and the importance of careful, continuous analysis and evaluation of the target setting. Further, reflection on research experiences together with related theories and models (pertaining to curriculum development in general and the creation of exemplary lesson materials in particular) generated fewer abstract development guidelines for creating the desired program. The most concrete layer was the product specifications, which represented developer ideas on how to achieve the characteristics prescribed by the foundational tenets and the development guidelines for the content, support, and interface of the program. Detailed discussion of the design principles (as well as the CASCADE-SEA program) may be found in McKenney (2001a). Together with the CASCADE-SEA program itself, these design principles speak to the main research question insofar as they illustrate the characteristics of a computer-based support tool for secondary-level science and mathematics education in southern Africa that is both valid and practical, with the potential to have a positive impact on the performance of its users.

The aforementioned tenets influenced the design of the CASCADE-SEA tool, as well as the structure of this study. These tenets, together with the experiences gained through the CASCADE-SEA study, have produced understanding that may be useful in structuring future developmental research activities. They shape the recommendations in the next section.

Recommendations

Local relevance. Whereas the notion of designing educational innovation from an implementation perspective is not a new one (cf. van den Akker, 1994), determining how to factor in cultural and contextual realities remains a challenge. Tessmer and Harris (1990) spoke of a potential conflict of interest between following sound instructional design practices and paying attention to real world challenges and limitations. They made a distinction between “doing things right” and “doing the right things” in instructional design. Developmental research (particularly formative research) addresses this potential conflict through the combination of careful design based on validated models (doing things right) that is then tested and revised in practice (increasing the chance for doing the right things). Such successive approximation of interventions in interaction with practitioners distinguishes developmental research from other research approaches (van den Akker, 1999). Evolutionary development (fed by information from research activities), yields greater opportunity for coping effectively with contextual factors that may not have been present, evident, or articulated during earlier phases of development. This increases the practical relevance of that which is being designed, which, in turn, affords deeper insight into good design practice for that particular setting.

Collaboration. In a study such as this one, where significant emphasis has been placed on retailoring initial design ideas to best fit the context, the notion of collaboration bears mention. It was previously stated that the design and development activities should (where feasible and functional) take place in collaboration with, and not for, those involved. Although this may add complications to the design process, the potential benefits of a participatory design process make it worthwhile. A participatory design approach is distinguished from other, more traditional approaches by (among others) the assumption that users themselves are well equipped to determine how to improve their work and professional environment. Further, "it views the users' perceptions of technology as being at least as important to success as fact, and that their feelings about technology are at least as important as what they can do with it," (Schuler & Namioka, 1993, p. xi). In the case of CASCADE-SEA, user involvement was thought to help establish a better fit in terms of system design. That is, the input helped designers to better understand the context in which the program would be implemented, as well as to sharpen their understanding of user needs. Secondly, this approach can simultaneously foster ownership on behalf of the users, thus increasing the potential for the innovation to become accepted and implemented (or at least tried out) in the target setting. Finally, as with the creation of lesson materials, participating in the development process can contribute to professional growth. As researchers and respondents jointly reflect on how curriculum development takes place, and how that could be supported through the computer, both parties learn from the experience (cf. Nieveen, 1997).

Authenticity. Design and development activities should be integrated, where possible, with the existing endeavors taking place in the target setting. In the case of CASCADE-SEA, this meant that curriculum materials development efforts should be integrated into a framework of inservice education (or, in some cases, preservice education), which usually occurs at teacher resource centers. Using a concurrent design approach, prototypes can be developed together with the users, even while doing additional situational analysis (Tessmer & Wedman, 1995). This helps to optimize the link between teacher development and curriculum development within the given setting. In turn, it can increase the authenticity and, thereby, the overall richness and value of the results.

Mutual benefit. Embedding research activities into an existing framework of teacher professional development requires that the researchers exercise caution as well as creativity in selecting data collection methods. It must be made clear to the researchers, as well as those participating in the study, that the goals of the activities are not related only to developing a prototype. Rather, these activities must also serve the professional development of the participants. In this study, researchers were careful to maintain this dual focus throughout the data collection activities, which required imaginative approaches to collecting useful information while maintaining care for the better interest of those involved.

Continuous analysis. One way to maintain a dual focus is through the use of prototyping. Prototyping has traditionally been associated with engineering fields of study. Yet through time, this has grown to include other arenas that apply a systematic approach to problem solving and design. Tessmer (1994) noted that the advent of prototyping allows evaluators to review functional versions of products at an early stage, thus making formative evaluation more a part of the front-end analysis and design. This study involved users in the design process by continuously field-testing working evolutionary prototypes. For additional information on prototyping to reach product quality, please refer to Nieveen, (1999).

Epilogue

The reflections presented earlier ascertained that the desired quality aspects of tools such as CASCADE-SEA are neither absolute nor completely objective. Rather, they are relative to the context in which the program is used. In addition, the needs, expectations, and beliefs of individual users shape perceptions about quality. Further, the user–facilitator agenda determines, in part, the way in which educational technology is used. This study has highlighted the importance of continuously seeking heightened contextual understanding as an integral part of the design and development process. Having been warned against the "wholesale transplantation" of ideas (Ogunniyi, 1996), the CASCADE-SEA study has generated insight into how to research the design of interventions that are culturally and socially portable. Despite its own methodological challenges, it is our conviction that a developmental research approach has the potential to make a significant contribution in such efforts.

To date, little research has been published in the area of computer-based support for curriculum development in developing countries. And whether or not outputs of this study will be used to inform future activities remains to be determined. Yet the CASCADE-SEA expedition has shown that, if carefully embedded into existing activities where a need and a readiness exists, such an approach can be potentially advantageous. It is hoped that this realization will promulgate additional inquiries into this promising domain. □

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