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DEVELOPMENT ARTICLE

Development research of a teachers' educational performance support system: the practices of design, development, and evaluation

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Abstract This study adopted design and development research methodology (Richey & Klein, *Design and development research: Methods, strategies, and issues*, 2007) to systematically investigate the process of applying instructional design principles, human–computer interaction, and software engineering to a performance support system (PSS) for behavior management in a classroom. The purpose was to examine how a proposed instructional design framework based on Ausubel's (*The psychology of meaningful verbal learning*, 1963) advance organizer theoretical approach could be used to address inherent problems of technically driven PSSs. Development data were collected from a six-phase participatory rapid prototyping process using both qualitative and quantitative methods. Findings indicated that (a) the advance organizer concept combined with a matrix design metaphor provided an effective way to illustrate conceptual connections and relations among PSS modules and their elaborated information, (b) the system served as a reference to support participants for exchanging ideas with other teachers as well as with parents of students, and (c) the rapid prototyping process established parameters that helped the project team maintain a focus on users and collect data useful for advancing to a higher phase of system development. Potential drawbacks pertaining to the proposed design strategies and their possible corrective actions are also reported and discussed.

Keywords Advance organizer · Development research · Performance support system

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Development research is an instructional design and development research methodology in which the goal of the research is to inform instructional designers of how particular instructional problems have been identified and resolved through an empirically based and systematic study of the design, development, and evaluation processes (Richey and Klein 2007). By conducting design and development research, instructional researchers are able to explore and document the procedures used by the developers—how they identify alternatives and then proceed to make decisions about the most satisfactory among them.

Design and development research has become one of the important research methodologies in instructional technology, because it helps researchers understand the dynamic development cycle of a given instructional product (e.g., instructional event, learning system, or program) by actively collaborating with field practitioners and potential users. Through this collaborative process, researchers, field practitioners, and users are able to progressively refine the product "until satisfactory outcomes have been reached by all concerned" (Reeves 2006, p. 59). This collaborative refinement of an instructional product during its development cycle provides an opportunity to gain a better understanding of how the product's design principles can be used to attain effectiveness, feasibility, and acceptability in order to increase its future implementation. Recently, many researchers have proposed or conducted design and development research to advance the practice of instructional development (e.g., Jones and Richey 2000; McKenney and van den Akker 2005; Reeves et al. 2004; Reigeluth and Frick 1999; Richey and Klein 2007; Wang and Hannafin 2005). *Studying*, *describing*, *analyzing*, and *reporting* the design and development process of an innovative instructional product help developers to better understand how to apply theoretical frameworks to that process and how they should revise both the product and its design framework.

The present study followed the design and development methodological framework of Richey and Klein (2007) for tool development research to investigate the development of a performance support system (PSS) for teacher classroom behavior management. In conducting the study, we (a) started with a "design problem" that is inherent in a specific instructional system model (i.e., PSS); (b) surveyed relevant literature to propose a set of possible design and development solutions; (c) instituted multiple data collection methods to document the system development process; and (d) developed the instructional system. This article reports findings on the process and the developed system as they relate to effects of the proposed design solutions, the development model used to create the system, and its impact on participants.

The goal of adopting this development approach was to produce design knowledge (Clark and Estes 2001; Glaser 1976) that will facilitate refinement and increase understanding of how instructional design, human–computer interaction, and software engineering principles can be applied to the design and development processes to create an "instructionally integrated" PSS. According to Glaser (1976),

> "Given a set of alternative goals or possibilities for action, certain fixed parameters and constraints of the situation, and a function that describes the relationship between these factors, [design knowledge finds] a set of values that provides the best means of attaining possible outcomes." (p. 6)

Instructional researchers are interested in how to optimize instructional procedures so that they reflect the process of learning and match learners' needs. Through development research, researchers explore and document the instructional procedures used by the developers. The purpose of this study was to acquire design knowledge to enhance

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instructional design and development for successive improvement and refinement of possible alternatives.

Performance support system development

This study originated in an educational research project funded by a private foundation. The mission of this research project was to develop instructional plans and tools for support of in-service (and, ultimately, pre-service) elementary school teachers. These plans and tools were aimed specifically to help teachers learn behavioral management techniques that could help to prevent problems in the classroom, as well as manage specific problem situations. During field evaluation for the instructional tools, teachers indicated need for learning and training in the area of classroom behavior management. This expressed need led to a dissemination project in which a PSS prototype was designed, produced, and analyzed.

Study goal and research questions

Children with problems in behavioral regulation present inappropriate responses to environmental stimuli, particularly a lack of behavioral inhibition (Chasnoff 2001). Teachers are often required to identify these problems immediately and generate effective short-term and long-term solutions to help a child learn. Researchers have incorporated computer-based tools to support classroom behavior management (Nickles 2006; Reinke et al. 2006). Such tools typically are designed for school-wide behavior support but do not provide just-in-time information (i.e., information that can be obtained and used immediately) to help teachers find appropriate solutions to the problems they encounter.

This study's goal was to examine how teachers perceive, react to, and use a classroom behavior management performance support system in an actual work setting during the system development process. The study incorporated design and development research intended to systematically explore the consistency and effectiveness of an instructional tool's design, development, and evaluation process (Richey and Klein 2007). From the study of this systematic process, the researchers sought to gain and document a detailed understanding of how the design affects teachers, as well as issues that arose during the development process and their resolution. The following design and development research questions were examined in this study. First, how are design strategies realized in the development process? This question guided our research in the design and development processes. Second, how do specific design strategies affect the teachers' development of intervention strategies? This question guided our research in the evaluation process.

Method

Participants

Thirteen teacher participants from the private foundation's existing 28-member focus group agreed to participate in this study. They were elementary or junior-high school teachers from three school districts in the suburban Chicago area. Three were resource teachers and ten were special education teachers. Participants completed a 10-month,

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six-phase system development evaluation process, including assessment, design, prototyping, planning, action, and audit.

In addition to the thirteen participants, two university professors (from instructional development and special education, respectively), a pediatric doctor, a retired special education teacher, a clinical psychologist, and a software engineer who specialized in relational database development also served as subject matter experts (SMEs) in expert appraisals during the development of the system design. Additionally, the project design and development team consisted of three content experts, one educational software developer who was also the primary researcher, and one media developer.

Procedure

The study adopted a rapid prototyping process (e.g., Jones and Richey 2000; Tripp and Bichelmeyer 1990) to operationalize system development, data collection, and evaluation in a structured, consistent, and systematic manner. Rapid prototyping is a method commonly used in software engineering to bring project sponsors, users, content experts, and a project development team together to discover effective solutions to dynamic problems through a seamless iterative process of designing, constructing, and evaluating prototypes (Pressman 1992). When developing the system prototype, rather than minimizing the task by merely developing a *mock-up* version of the system, we explored all possible tasks involved in full-scale development by engaging in a *small-scale* version of the design and development process. Thus, the prototyping could be applied within a short period of time to portray the characteristics of the full-scale version (Tripp and Bichelmeyer 1990).

The rapid prototyping process was divided into six phases based on its purposes and intended outcomes. Each development phase adopted a distinct set of data collection methods to meet its unique needs and to address the complexity of the development process. In this section, data collected from each phase are reported and reflections about the development process are described to document the nature of real-world instructional system development. Table 1 summarizes the research purposes, participants, methods, and instruments used in the development process for each phase.

Results

Phase 1: identifying inherent design problems of technically driven PSSs

Although the design framework of a PSS has not been clearly defined in the extant literature, the major technical characteristic of such systems have been identified as a module-based approach, which allows for flexibility in the exchange of modules to support just-in-time learning and enhance employee performance (Barker and Banerji 1995; Tjahjono and Greenough 2002; van Schaik et al. 2002). Based on this technical characteristic, a PSS offers designers a way to integrate multiple instructional modules (such as a tutorial, hypertext, advisory systems, information management systems, and collaboration tools) into a package with a common interface that provides users with a helpful system for dealing with various tasks and problems encountered in their work environment. However, such a generic design approach is potentially problematic because it relies completely on technology to “glue” all the modules into one unit with an interface as the packaging.

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Table 1 Research purposes, participants, methods, and instruments by phase

Phase	Purpose	Participants	Methods	Instruments
1. Identifying PSS design problems	Identify an instructional design theory to guide the design and development of the proposed PSS	Researchers	Literature review	N/A
2. Eliciting user requirements	Determine how teachers develop behavioral intervention strategies, what skills and knowledge are needed when dealing with classroom management issues, and how PSS functionality can support learning and on-task performance	Target user group ($n = 13$)	Focus group on system functional requirements	1. User profile survey 2. Twelve PSS module selection list
3. Designing system architecture	Create a fully interactive storyboard to represent the visible contents of each screen and system interactivity for assessment of content accuracy and system enhancement	Project team ($n = 5$)	Advance organizers and information architecture	N/A
4. Expert system appraisal	Enhance system design by expert assessment	SMEs ($n = 6$) Project team ($n = 5$)	Two sessions of expert appraisal using the Delphi approach	The fully interactive story board created in phase 3. 75-item checklist
5. Prototyping	Convert storyboard into fully functional prototype to: (1) detect usability problems; (2) determine which features in the system prototype could be improved for field usage; and (3) assess users' initial reactions toward the prototype	Target user group ($n = 7$)	Two iterations of system usability testing	System prototype
6. User system appraisal	Implement system prototype in participants' work environment to identify potential practical constraints that could hinder use in a real-world setting Assess system design framework for supporting participants in making informed decisions, and effective way of integrating a fully developed system into the classroom environment	Target user group ($n = 13$)	Action learning with a set advisor	System impact survey, post interviews and activity log analysis

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By integrating modules through a common interface, the PSS is merely "technically integrated," but not "instructionally integrated." That is, each module is linked and connected by the interface alone. Such an interface, if appropriately designed, should help users navigate among modules with ease (e.g., via effective arrangement of screen elements) and provide improved orientation to the system's technical structure (e.g., through uniform and consistent screen layouts). However, these factors may not be enough to support content comprehension and problem solving activities that are inherent in the learning and performance goals of a PSS. This is because users are still working with separate system components without additional guidance to lead them to other relevant modules. To support content and learning activities, an effective PSS interface should incorporate scaffolding attributes, such as incorporation of a decision matrix, information mapping, and advance organizers, to help users anchor their knowledge and skills acquisitions in meaningful contexts (Hung and Chao 2007).

In addition, because traditionally each PSS module is functionally independent, the result could be a *catch-all* style design; i.e., the designer hopes that at least one of the many modules will be useful in order for the whole system to have value. This is a passive design approach that does not provide structures and relationships among components to encourage users to take full advantage of the activities and support contained in each component. Such a design is also heavily technology-driven, and designers ultimately may be preoccupied with technical problems rather than with supporting users. To overcome the problems caused by a generic, technology-oriented approach, PSS design should begin with the integration of a theory-based design approach to realize the full potential of the application of technology and to gain the confidence of users (Koschmann et al. 1996). This approach can also help organize, structure, and evaluate relevant technical components to enhance on-the-job task learning and performance gains.

Koschmann et al. (1996) proposed a four-step process to operationalize a theory-based design approach. The first step is to articulate the desired instructional features of the planned innovation with known capabilities of technology. Step two is to analyze current practice in light of the design goals. The third step is to develop a specification based on both instructional requirements of the setting and the known capabilities of technology. Step four is to produce an implementation that allows for adaptation to instructional practice.

Although this theory-based approach targets the design of computer supported collaborative learning (CSCL) tools, its principles are sufficiently flexible and generic to serve as a guide to conceptualizing an instructionally oriented PSS. Through each step, the project team was able to systematically develop appropriate instruments and data collection methods to elicit users' system functional requirements in Phase 2, and then use the data collected to design the system architecture in Phase 3.

Phase 2: eliciting users' functional requirements

In Phase 2 of the development process, the project team's goals were to elicit and assess (a) how teachers currently develop intervention strategies for classroom behavior management (though a profile survey), (b) what skills and knowledge are needed to become a proficient problem-solver when dealing with classroom management issues (first focus group), and (c) how PSS functionality could be incorporated to support learning and on-task performance (second focus group).

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Prior to focus group interviews, all 13 participants completed a user profile survey to obtain data concerning their computer usage and experience with classroom behavior management. Analysis indicated that the mean teaching experience of the participants was 10 years, and they all had participated in at least two training workshops for classroom technology integration. Furthermore, participants seldom relied on book or computer references (e.g., searching the Internet for relevant resources) to assist in their development of classroom intervention strategies; they were expected to act independently to resolve their daily classroom behavior issues. These findings suggested that the design of the PSS should feature a consistent interface to support user interaction with self-contained modules that guide users to relevant behavioral intervention strategies. Survey findings helped the project team plan the focus group questions.

All 13 teachers participated in two iterations of the focus group process. The first iteration aimed to determine how the proposed system could further support teachers' individual performance in resolving their daily classroom behavior issues. The second iteration elicited participants' preferences from a list of potential system functions derived from the first set of responses.

Important findings emerged from responses during the first interview regarding participants' experiences with classroom management. First, the problems that participants encountered often required immediate attention. Second, participants were accustomed to solving these problems on their own or with parents of the students, unless the problems were beyond their capability, in which case they would turn to the resource teachers. Third, the limited availability of resource teachers, the lack of explicit guidelines about classroom behavior management, and the large number of students in the classroom encouraged the participants to plan their own interventions without seeking help.

From the user profile survey and first focus group interview, the team concluded that a system focused on individual just-in-time performance and on-going support merited development. The researchers generated a list of 12 possible PSS modules that could potentially meet the participants' needs as well as their technology experience. This list was then distributed in the second iteration interview to elicit participants' opinions. When the participants were asked to choose from the possible system modules the ones they would like to have incorporated into the proposed PSS, the majority agreed that a feature-rich content knowledge base would be most beneficial to them in finding relevant and usable information for their development of intervention strategies. A majority also favored a system module for them to apply the knowledge that they acquired and a system module for collaboration opportunities among resource teachers and parents. Participants also indicated that a mechanism for managing their development of intervention strategies and keeping track of the implemented interventions would help them document their efforts in classroom management and enhance their instruction in the classroom. Table 2 presents the findings and design implications of this system module selection process.

Phase 3: designing the system architecture

In Phase 3, the project team converted the system functional requirements to a system design specification by developing a series of design strategies. Applying rapid prototyping, the team created a fully interactive storyboard of the system interface and navigation structure based on the selected design strategies and modules. The goal was to represent the visible contents of each screen (e.g., graphic, text, title, and video) and system

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Table 2 Findings and design implications of the system module selection process

Possible PSS module	Importance to users	Design implications based on participant feedback
Quick reference	Extremely important	Allow teachers to develop just-in-time behavioral interventions. Needs to be a flash card like tool that can be printed in case the computer is not available
Knowledge database	Extremely important	A content specific, multimedia-based, fully searchable database
On-line support center	Extremely important	Provide up-to-date information, events, and resources on behavior management subject matter
Skill builder	Important	Provide self-directed learning activities on the design and evaluation of behavior interventions
Record keeper	Important	Allow teachers to track their personal performance on the development of intervention strategies and learning activities
Collaboration	Important	Make available through the on-line support center and allow users to configure their own collaborative group
Case study	Neutral	Could integrate the case study feature in both knowledge database and skill builder modules
Expert consultation	Neutral	Could be a listserv or blog available through the on-line support center
Resource referral	Neutral	Could be available through the on-line support site
Interactive tutorial	Neutral	Could integrate with the skill builder module and present as a general overview of classroom behavior management
Chat room	Unimportant	Only available through the on-line support site
Threaded discussion	Unimportant	Only available through the on-line support site

interactivity that the users would encounter. Microsoft PowerPoint® was used to visualize the content of every screen and the flow among the screens.

At the beginning of the storyboarding process, the project team structured the system design framework around the support of individual performance needs by providing a set of performance and reference tools that could help users address their immediate needs, while also offering opportunities for knowledge advancement. Based on the focus group outcomes, five system modules were selected and adopted: (1) a knowledge database (the interactive content module) to help users acquire in-depth information about behavior disorders and classroom behavior management; (2) a quick reference module (a behavior matrix) to support users just-in-time performance in their classroom behavior management; (3) a skill builder module to provide users opportunities for learning through guided experience and to model the process of how experts solve a particular problem; (4) a record keeper module to collect and store behavior information in an orderly manner and import information queried from both the quick reference and knowledge database modules; and (5) an on-line support center module to provide users with the most up-to-date information about behavior interventions, and to enable collaboration. The selection of the five modules was determined by how important the system modules were to the participants, and how the system modules could support general problem solving approaches used in the field of clinical psychology.

In order to design a PSS that was integrative, performance-centered, and instructionally purposive, the project team next incorporated features of instructional design principles

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and information architecture (Rosenfield and Morville 2002) to guide integration of the five system modules. Three design strategies served to achieve this integrated framework: (a) expository and comparative advance organizers to scaffold content comprehension and problem analysis (Ausubel 1963, 2000), (b) a matrix metaphor to guide users' access to the PSS modules and content retrieval, and (c) a grid-based interface design to integrate the modules. The relationships among the integration strategies, theoretical support, and design procedures used in this study are outlined in Table 3.

Table 3 Proposed integration strategies, design purposes, and methods

Integration strategies	Design purposes	Method
Scaffold users' content comprehension and problem analysis through advance organizers	1. Guide the selection of PSS modules (together with the matrix design strategy) 2. Meet expert/user expectations 3. Raise users' cognitive awareness of the unfamiliar domain knowledge that will be learned/performed	1. Begin with a comparative organizer to provide ideational scaffolding for the content materials to be learned 2. Add expository organizer to provide inclusive information based on the information residing in the comparative organizer 3. Incorporate expert/empirical based strategies and actions to operationalize information learned from both organizers
Guide and lead users' content retrieval and access to PSS modules through a matrix metaphor design method	1. Guide the selection of PSS modules (together with the advance organizer design strategy) 2. Transform the conceptual framework of expository and comparative organizers into a work panel for problem identification 3. Provide visual overview of content materials to remind and give hints to learners about subsequent tasks to be performed	1. Use a single screen interaction approach to improve comprehension of content presentation and minimize navigation loss (Hammond 1993) 2. Structure information in table format to increase the learning materials' application and context relevance (Berkey 1973) 3. Use hypertext technology to give users access to in-depth information as necessary for comprehension
Visually unite the selected PSS modules with a grid-based interface design method	1. Create an identical interface for all system modules to ensure consistency in their look and feel 2. Minimize the extent to which users need to be aware of what they are doing 3. Increase users' knowledge of how to use available functions, rather than increasing their knowledge about some specific aspect of the structure of these functions	1. Develop a set of shared elements (e.g., print, bookmarks, note taking, glossary) to maintain consistency in the interface's navigation structure and orientation 2. Employ a grid design technique along with the "golden ratio" aesthetic principle to proportion the navigation structure and content layout 3. Divide the entire window into blocks of equal size and then assign a certain number of blocks to each area

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Although studies on the effectiveness of advance organizers are mixed (see review of Clark and Bean 1982), the support of technology and a user-centered interface may create a design opportunity to scaffold user's just-in-time performance and content comprehension. The combination of hypertext technology and a matrix metaphor allowed the project team to graphically structure the behavior matrix module into (a) a single screen interaction to minimize navigation loss, (b) a three-way information structure to increase the relevance of content materials, and (c) a visual overview of learning materials that can remind and provide hints to learners about subsequent tasks to be performed.

In adopting Ausubel's advance organizer design concept (Ausubel 1963, 2000), we used both expository and comparative advance organizers to select and sequence the PSS modules. We started with content and learner analyses to determine what amount of content information experts would deem adequate to help teachers develop behavior intervention strategies, and also to identify what participants knew about classroom behavior management. Based on that information, we created a behavior information organizer that contained the inclusive content material. This behavior information organizer can be used to identify behaviors that students exhibit (i.e., over-controlled, under-controlled, and mixed), analyze specific types of behavior (e.g., withdraw, off-task, and bother others), and identify intervention strategies that are appropriate for the specific type of behavior. A progressive differential design (Ausubel 2000) was used to raise teachers' cognitive awareness of the unfamiliar domain knowledge to be learned or performed. This progressive differential design also scaffolds a systematic process used by experts to solve various behavioral problems including problem diagnosis and root causes analysis, problem context evaluation, and the development of appropriate interventions.

Graphically, the expository and comparative advance organizers were mapped into four visual areas. Specifically, these are areas for (a) comparing teachers' existing knowledge with new knowledge (i.e., how much they know about the three types of behavior through hypertext links), (b) exploring inclusive information about new knowledge, (c) exploring applications of inclusive information (i.e., interventions), and (d) selecting application strategies for the inclusive information. These four visual areas were then integrated and sequenced into a multi-dimensional matrix structure. Within this matrix structure, presentation of the inclusive content occurs on a single computer screen to provide teachers with a holistic view of the content materials as well as their inter-relationships, thereby providing a potentially meaningful learning environment. Figure 1 shows how these four visual areas were integrated and sequenced in the multi-dimensional matrix structure to create the behavior matrix module. Each cell is a hyperlink to a definition, an explanation, or an example for that item.

The grid-based interface enabled the project team to integrate all system modules into a consistent "look and feel." The purpose was to minimize the extent to which teachers need to attend to specific aspects of the various functions while increasing their knowledge about how to use these functions efficiently (Rosenfield and Morville 2002). To create this interface, the project team first divided the entire screen into three fixed areas for placement of module label (e.g., headings, banner), system function (e.g., print button, bookmarks, notepad, and glossary), and content. Factors that the project team considered for the placement included the size and color of elements in the display, their shape, and positioning. Similar placements for labels, system function, and content were made to the remaining four system modules.

The theory-based approach enabled us to employ instructional design models and learning theories and to help organize, filter, and structure relevant information for learning. The adoption of advance organizers helped us focus on the users and their

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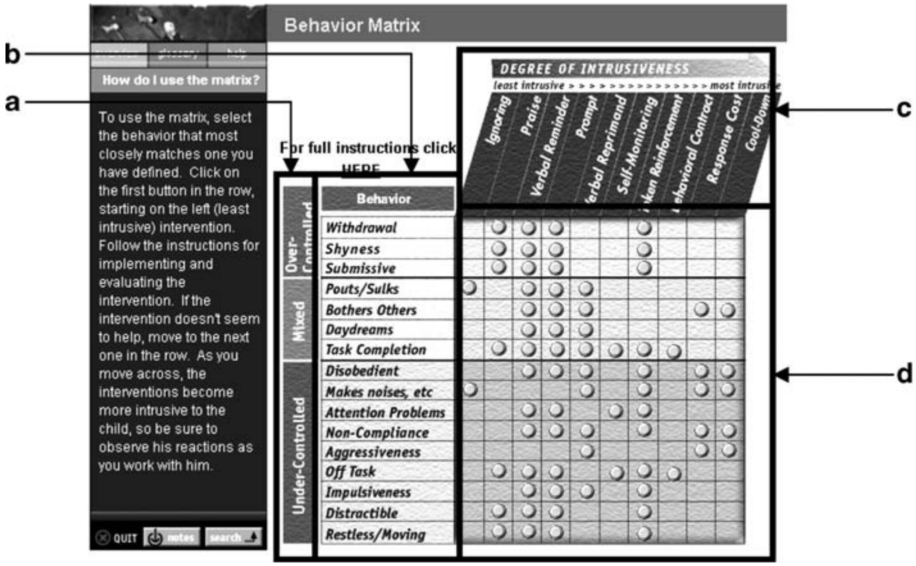

Fig. 1 Screen shot of the behavior matrix module

performance goals. The use of a matrix metaphor enabled us to structure content that allows quick cross-referencing and decision-making. The grid interface also gave the five system modules a consistent look and feel. These design strategies helped to ensure that the system was functional throughout the development process.

Phase 4: system appraisal

In Phase 4, the six SMEs participated in two Delphi sessions of expert appraisal, following the recommendations of Vennix and Gubbels (1994). The first Delphi session was conducted as a one-on-one appraisal session to obtain each SME's opinions and understanding of the design structure and system module integration. The fully interactive PowerPoint storyboard with a system appraisal checklist was distributed to each SME. The checklist contained 75 yes/no questions that were divided into three main constructs: instructional features, interface and orientation, and technical accuracy. The purpose of the checklist was to provide the SMEs an overview of each system module's functionalities and how the five system modules were integrated to serve both performance and reference needs. For example, one checklist question pertaining to instructional features was "use of cues and prompts to guide further exploration of additional reference materials." If the SMEs believed the feature to be important, they would mark the item "Yes." Data from the individual checklists were collected and summarized.

For 12 of the items, fewer than five out of six SMEs checked the same response. There were five items from the instructional features construct that concerned module and topic sequence, navigational depth of behavior management content, and user data record format; four items from the interface and orientation construct that pertained to icon appearance, button size, and reversal of undesirable action; and three items from the

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technical accuracy construct that involved feedback on task completion and labeling. These 12 items were redistributed in a second Delphi session for group discussion and to elicit suggestions for improvement.

Before administering the second Delphi session, the project team made a minor revision to the storyboard to address a number of immediately obvious concerns, such as the size of navigational icons and content headings listed in the 12 non-consensus items. This revised storyboard, along with the 12 non-consensus items, were then brought to the second Delphi session. All six SMEs met together in a 2-h session to ascertain the practicality and versatility of the design structure and system modules and to discuss possibilities for enhancement and improvement. Each of the 12 items was presented to the SMEs. The project team collected their feedback and then attempted collectively to decide to revise or delete each non-consensus item.

For example, when discussing the navigational depth of behavior management content, the instructional technology professor and clinical psychologist both felt there were too many layers of matrix content and the size of pop-up windows was too small. In addition, the special education teacher felt the content was disorganized and difficult to follow. To respond to these concerns, the project team made immediate adjustments directly to the storyboard (e.g., resizing pop-up windows, labeling the content, and chunking information into an embedded hypertext window) according to the feedback from the participants. Such adjustments continued until a majority of SMEs agreed with the redesign.

Results from both iterations of the Delphi process showed differences between the SMEs and participants from the focus group. For example, the participants were interested in finding the quickest way to use the system to support their work. Therefore, identifying system functions (e.g., on-line support, searchable database, and quick solution list) that provided the easiest and fastest way to help users solve a problem became the most discussed issues during the functional requirement and refinement process. This was contrary to expectation of the SMEs, which was that the participants would acquire a more thorough knowledge of the subject from the system rather than use it as a “quick guide” to address problems using a list of predefined solutions.

In the second Delphi session, the instructional development faculty member suggested using the quick reference module (the behavior matrix) as the entry point for the entire system. Group discussion focused on how this module provides users with quick access to possible solutions (i.e., interventions) and their contextual relationships with types of problems encountered (i.e., behaviors). Thus, while users are making decisions on appropriate interventions, the matrix design metaphor allows them to explore and acquire in-depth domain knowledge through each intervention’s embedded hyperlinks to other relevant modules. This allows users to “make use of established knowledge to increase the familiarity and learnability of new materials” (Ausubel 1963, p. 87). For example, when users wish to acquire additional information regarding an intervention listed on the matrix, they can “click” on that term to bring up a multimedia knowledge base module to explore the domain information in depth. In this way, the behavior matrix module serves as a “working panel” by which users gain access to the system functions without having to understand or select them explicitly.

Figure 2 shows how the matrix-based behavior information organizer allows users to explore and request additional in-depth content materials through appropriate modules. This approach also was supported by the pediatric doctor and software engineer who believed it would systematically guide the users in navigating through each system module. Thus, the Behavior Matrix became the entry point.

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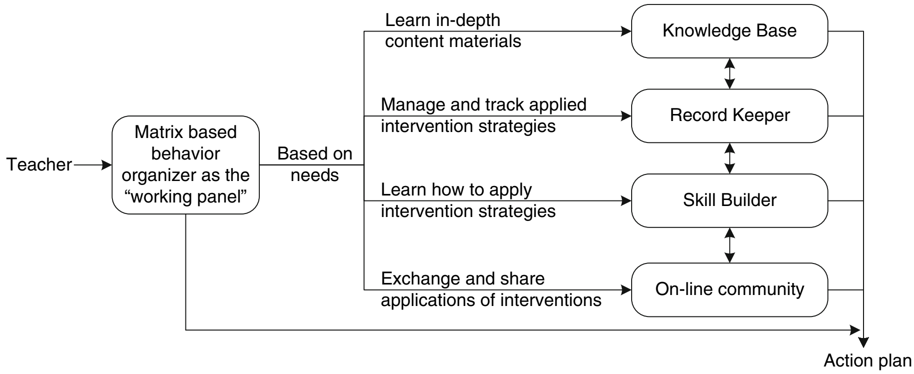

Fig. 2 Interrelationships of modules, accessed as needed

Phase 5: prototyping

In the prototyping phase, the storyboard was converted into a fully functional prototype based on the proposed design strategies and data collected in the system appraisal phase. The development tasks involved in Phase 5 were, for the most part, technical and involved tasks such as database integration, programming, and system authoring. During this phase data were collected from users through a series of one-on-one usability tests to (a) detect any usability problems associated with system navigation and interactions, (b) determine which features in the system prototype could be improved to become more workable (or complete) for field usage, and (c) assess users' initial reaction to the prototype.

Two iterations of usability testing were conducted. The first iteration was administered during the conversion from storyboard to actual system. When each system function was converted, the project team invited staff members (within the organization), friends, and content experts to test that function, then complete an activity that involved testing the stability and workability of each function. For example, when the project team completed a section of the interactive contents, they asked testers to test its hyperlinks and content legibility. If testers detected any error or provided interaction feedback, the project team either corrected or revised the function and then tested it again until the section appeared to be as stable and workable as possible. Once that testing was completed, the project team converted another system function and then repeated the testing cycle. Finally, the fully converted system prototype was compiled as an executable system for the second iteration of usability test.

In the second iteration, rather than testing each system function's conversion individually, we took a holistic approach to refining the system prototype by evaluating its initial ease of learning, efficiency, memorability, and subject satisfaction, as defined by Nielsen (1993). This iteration of the usability test adopted user testing and observation of users in a laboratory setting commonly used in the field of human–computer interaction (Rosson and Carroll 2002). The design of the usability test was to provide a set of navigation tasks and observe how the users performed the tasks using the system, what errors they made, and how they reacted to the prototype.

For example, the project team provided a classroom behavior scenario and asked participants to match the behavior with the appropriate degree of intrusiveness in the behavior matrix. The project team then evaluated whether participants (a) could correctly use all menu buttons on the matrix, (b) could read the content from the screen without trouble,

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(c) had difficulty with the three-way interactions of the matrix, and (d) were satisfied with the level of interactivity and their content comprehension. In addition, the team also tracked (a) the name of any task with which the participants expressed difficulty and frustration, and the number of times they did so; (b) the average time to complete an information search using the search function; (c) the number of errors; (d) the number of times the participants had to work around an unsolvable problem; and (e) the time spent on each task.

For convenience and cost control, seven participants from the original participant pool of 13 who resided in the Chicago area were selected for the usability test. Determination of this sample size was based on Dumas and Redish's (1999) usability guidelines, which recommend 5–12 participants to attain reliable usability information to validate a prototype.

The usability test followed Dumas and Redish's task-based usability procedure to measure the time needed to complete a set of required tasks, record the number of steps needed to complete the tasks, and record any errors made. At the beginning of this test, we briefly introduced the system to each participant. Once participants understood the purpose of the prototype and its functionality, they were asked to perform a set of tasks that required interaction with the system's functions. An evaluation aid containing evaluation tasks, operation questions, and a quick reference to the system interface served to guide the evaluation activities. A brief discussion with each participant followed the usability test to ascertain overall feelings about the prototype and to solicit suggestions for improvement.

Data obtained from the usability test, including both qualitative information (e.g., observation and comments) and quantifiable measurements (e.g., time, error rate, and frequency), were matched and analyzed for key patterns or themes (i.e., common occurrences of problems and errors) to explore possible improvements to the system's overall usability. A categorization method was developed to determine the patterns and themes in the data. This method was based on the system prototype's functions and interactivity. Three major themes emerged from the data: (a) windows, (b) interactions and feedback, and (c) global impression of the system prototype. These categories were further partitioned into subcategories based on shared elements.

After the data were analyzed and categorized, the project team began to revise the final version of the system prototype based on participant feedback. Note that feedback about the content and new features of the system prototype was not used for revising the current prototype but rather was documented as a reference for future development of the fully functional system. For example, when dealing with the content search function, the project team made revisions to its interface (based on the participant feedback) by adding save and keyboard shortcuts, but documented "option of search within a particular system module and ways to identify types of content" as features for future implementation.

Overall, participants had positive reactions to the system prototype. Specifically, they felt that the interface was easy to use and the screen design was appealing. The interaction and feedback provided adequate information to inform their actions. The screen layout was legible and promoted awareness of features that were embedded in each system function. An inadequate help function, however, prevented them from exploring the system in depth. Several participants reported feeling insecure about control during their interaction with the prototype. Although the project team had initially identified participants' levels of computer usage from the user profile survey, feedback from the usability test indicated that training on the use of the system was needed prior to the users' system appraisal, so as to acquire more in-depth information about the usage and impact of the system.

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The two iterations of usability testing in the prototype phase were primarily focused on the interface design and system structure so as to evaluate the system's initial usability and participant satisfaction. In the next phase, the developed and tested system prototype was tested by the participants in the field to further explore possible effects of the system.

Phase 6: user system appraisal

In Phase 6, the goal was to implement the system prototype in the participants' work environment to identify potential practical constraints that could hinder the use of the system in a real-world setting.

Prior to implementing this phase, all 13 participants attended a 30-min training session on system usage. Each participant received the system on CD with a quick start job aid (in addition to the system's embedded help system) to help them use the system prototype. Following the training session, participants were asked to use the system whenever they encountered classroom management problems with their students over the course of the subsequent 2 months.

Asking participants to address real-life problems as a learning exercise is similar to action learning. As such, the project team divided the 13 participants into three groups based on their school affiliation and invited each group to form an action learning set where group members could collaborate via the system prototype in developing intervention strategies for their students' behavior problems. The clinical psychologist from the SME pool became the set advisor to facilitate the action learning process. While the participants were carrying out the action plans they had developed for their students' behavior problems, they addressed issues of implementation with the set advisor and their group members.

At the beginning of the user system appraisal, the set advisor created a "Scavenger Hunt" through some of the system modules to familiarize participants with their content. This "game" was intended to be completed quickly, yet also to ensure that all participants viewed important sections of the system. It also was intended as a tool to facilitate thinking about how they could use the system in their groups.

After the participants were familiar with the system, all three action groups were encouraged to use the system as often as they wished. The set advisor conducted weekly on-line discussions to answer participant questions that arose in the process of applying the interventions in their classroom environments.

At the end of the user system appraisal, a 52-item Likert response scale, short-answer questionnaires on system impact, interviews about participants' experiences and perceptions, and analyses of activity logs were used to assess the system design framework for supporting participants in making informed decisions, and to explore better ways of integrating a fully developed system into the classroom environment. Interviews with the set advisor and the three action groups were also conducted after the survey was administered.

Overall, the results of the field test yielded three major conclusions concerning the next iteration of system development. First, participants confirmed that the matrix format provided them with a quick reference and guidelines to help them more accurately categorize their students' disruptive behaviors and apply proper intervention strategies. The layout and information query structure in the behavior matrix also guided participants to navigate through other modules as supplements. This navigation helped them understand the background information for the interventions and to retrieve more relevant information or strategies that they could use to develop more thorough interventions.

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Second, participants reported that by using the behavior matrix as a guide to develop their intervention strategies, they were able to establish common ground and communicate with parents and regular classroom teachers using the same language. When there was a need to increase the degree of intrusiveness of the interventions, all participants were able to look at the matrix and come up with a decision about which intervention strategy they would apply.

Third, it was clear that the concept of PSS was acceptable to the participants, even though they did not fully understand its technology. The advance organizer concept, matrix design, the practicability of the task, and the relevance of the contents were all contributing factors in the success of the technology.

Concerns also arose when applying the list of interventions and information presented in the system. In particular, participants were concerned about the rigidness of the matrix and lack of environmental and cognitive components in the system. They felt that, by providing quick cross-reference and instant possible solutions to target behavioral problems, the matrix design at times forced them into accepting interventions. That is, the one-to-one matching process (one behavior to one intervention at a time) inherent in the grid design approach could potentially lead a participant to feel the intervention was dictated.

In reality, because the situation was usually ill-defined, the most appropriate solution could not be determined without contextual information. Therefore, additional grids such as environmental conditions and cognitive conditions of the child may be necessary to make the system more comprehensive. In addition, tutorials and instructions that advise new users about the adoption of the interventions should be provided to minimize the authoritative feel of the system. Such suggestions lead to the question of user customization. Most participants wanted the matrix to be user customizable, with potential for additional content grids and interventions. Also, an individual student's behavior matrix should be generated so that the teacher could customize the interventions to individual students and thereby integrate the system with each student's IEP (Hung and Lockard 2007).

Discussion

In this study, the use of an integrated design approach (rapid prototyping, advance organizer, and information architecture) demonstrated potentially usable combinations for developing PSSs. Rapid prototyping provided guidelines to maintain quality and usability in the system prototype creation. Information architecture (matrix and grid interface design) enabled both adjustment and implementation of system functions as well as navigation structure. The advance organizer based instructional design approach guided the project team in making instructional design decisions regarding the workability of suggested design strategies and the accuracy, structure, and clarity of contents. However, this does not imply that other design approaches are necessarily inferior to the integrated design approach. Each design approach has unique attributes that can contribute to distinct types of settings or tools.

While an array of PSS-compatible modules can be mixed and matched, doing so should be guided by theoretical framework and by looking for features and functionality that facilitate users' learning and performance. In this study, the project team chose the advance organizer based instructional design approach to avoid the *catch-all* problem typical in the PSS design framework. In our approach, each module was incorporated and sequenced according to Ausubel's (1963) subsumed process. The goal was to enable the system to

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actively scaffold the participants' reasoning process and to support the development of metacognitive skills. That is, as users study a problem, build hypotheses, and generate learning issues, they begin to demonstrate problem-solving similar to that of an expert.

For example, when the system is opened, users begin in the behavior matrix module. Within the matrix, they diagnose, analyze, and identify the causes of the encountered problem and then develop an appropriate "just-in-time" intervention strategy. In this way, users are able to focus on the problem encountered without being burdened by their interaction with the system. When in-depth knowledge discussion and explanation are needed, users can explore elaborated information concerning the developed "just-in-time" intervention strategy through the embedded links in the matrix. These embedded links allow the user to click on a cell and bring up a list of in-depth discussion points for the specific intervention strategy, including theoretical discussion, implementation, evaluation, and assessment. These in-depth knowledge discussions and explanations are part of the interactive contents and skill builder modules. The user who generates the action plan can explore the information gathered from both modules to gain an in-depth understanding of the concepts and issues of the action plan, then save it to the system's record keeper module for future reference.

When the system was tested in the action phase, the set advisor and participants were not only target users of the system, but also acted as experts to assess its feasibility and practicability for teachers to use as a performance tool to support their classroom behavior management needs. Data collected from the user system appraisal suggested that incorporation of an advance organizer based instructional design approach facilitated participants' cognitive awareness when exploring and searching for relevant information. As the entry point for their problem inquiry, the behavior matrix provided a checkpoint to help participants critically examine the usefulness of their past behavior management experience by comparing it with the matrix's suggested interventions, and in this way helped them to determine appropriate strategies. The list of interventions and corresponding applications presented in the matrix allowed participants to compare options and assess each intervention before they applied it to students.

Furthermore, the format and information query structure provided in the matrix guided the participants to broaden their development and use of interventions and to create a dialogue for exchanging ideas with other teachers as well as with parents. They were able to discuss, refer to, and use their interventions based on a common understanding that was laid out in the matrix. As the matrix was shared among teachers during the action phase, it helped the set advisor establish a shared dialogue toward a common goal—to determine appropriate interventions for their behavior management issues. This shared dialog, mediated through the matrix, created a learning community in which participants could collaborate and exchange ideas that improved their learning experiences and knowledge base.

While all participants had a very positive reaction to using the PSS prototype, there were concerns about its practical implementation in the real-life setting. First, the intervention strategies provided in the matrix focused on conditions of child behaviors and lacked inclusion of social and family influences. While both social and family considerations are available through the matrix's embedded hyperlinks, users may not use or find them since they do not appear directly in the matrix. Such issues may lead to misuse of intervention strategies. Second, central to the change process is the ability to discuss strategies and techniques. The PSS prototype (i.e., the *Behavior Matrix*) may be useful for the participants' just-in-time problem solving, but its grid format may inhibit their deeper understanding of the underlying principles of the applied strategies and techniques. Third, critical to the change process is ready access to the *Behavior Matrix* for its models and

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reflections on intervention strategy development—ideally it should be accessible from home or other non-school sites (e.g., libraries).

In summary, the project team believes that the design strategies proposed in the study provided a potential solution to address the typical PSS's technology-driven and *catch-all* style design approach. Specifically, the advance organizer conceptual framework afforded participants a holistic view of the knowledge domains related to the problem and their inter-relationships and improved participants' awareness of available interventions. The matrix design metaphor presented an effective way to illustrate connections and relationships among concepts as well as their elaborated information using a single screen, three-dimensional approach. Finally, the grid-based interface improved orientation and navigation by helping participants recognize which additional system functions they could use to support their problem solving.

This study explored an alternative methodology and design approach for investigating the worthiness of instructional learning programs before they are fully developed. In particular, the use of a small-scale, rapid prototyping process to study the attributes of the system's acceptability and usability provided practical findings and user feedback to determine the worthiness of full system development, as well as providing an effective framework for assessing the feasibility of specific design approaches in the development of a fully functional system.

The adoption of design and development research methodology has shed light on the process of instructional system development. Although the present research methodology resembled the formative evaluation of an instructional tool, information collected during design and development research is primarily used to inform instructional designers how particular problems have been solved or overcome (Reigeluth and Frick 1999). The three design approaches used in this study, combined with their theoretical assumptions, were devised and justified through a series of inquiry, analysis, development, and testing processes. The shaping of an instructional tool during its development provides an opportunity to better understand how instructional principles can be used to increase that tool's usability. In addition, this process uses continual revision to assure effectiveness, feasibility, and acceptability for the tool. Thus, this shaping process provides one analytical method for carrying out design and development research methodology.

In conclusion, we believe that the adoption of design and development research as a methodological approach was appropriate because it facilitated "the study of new models, tools, and procedures so that we can reliably anticipate their effectiveness and efficiency" (Richey and Nelson 2001, p. 1240). The suggested design and development research framework (i.e., identification of the design problem, survey of relevant literature, development of the system, institution of multiple data collection methods, and report of findings) provided us with a conceptual guide to not only maintain a systematic approach to the development process but also to broaden the perspective of the system's instructional implications to a holistic approach that addressed system, user, and development process as a whole.

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