

DEVELOPMENT AND PILOT TESTING OF A COMPUTERIZED ATLAS OF
PERIPHERAL BLOOD SMEARS AS A JOB AID FOR PRACTICING CLINICAL
LABORATORY SCIENTISTS

By

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ABSTRACT

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The purpose of this project was to design and create a computerized atlas of peripheral blood smears which could be used as a job aid for practicing clinical laboratory scientists (CLS). Current computerized hematology atlases are typically designed as tutorials resulting in a number of shortcomings for optimal CLS use in the workplace. A needs assessment was performed to determine if professionals agreed that there was a need for such a program. The needs assessment indicated a general consensus for the need of a job aid such as this one. Digital images were produced from a large number of peripheral blood smears and edited. A database of text and 192 images was created and integrated into an interactive CD-ROM. The program was designed based on a detailed storyboard and built using *Macromedia Director*®. The atlas has been pilot tested for accuracy of content and usefulness in the workplace. The results and comments received from the pilot test were used to improve the atlas. The goal of this project was accomplished; the creation of an improved hematology computerized atlas with search options to guide workplace users. The computerized atlas has many advantages over previous computerized atlases. These advantages include a unique cell-feature search, a compare section, and a cumulative history of searches. The atlas has proven functional in the laboratory based on pilot test results.

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As creator of the atlas, I hope that it will inspire others to improve upon my idea, to take into account my suggestions and to create a superior hematology computerized atlas for the workplace. I am also hopeful that this atlas will inspire others to create a job aid for other clinical laboratory divisions.

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Introduction

A clinical laboratory scientist (CLS) is one who performs analyses of body fluids using manual and automated methods. CLSs are frequently generalists, working in multiple departments of the clinical laboratory including hematology, immunohematology, chemistry and microbiology. For a variety of reasons, laboratory managers must frequently cross train their staff, thereby creating more generalists.

A common laboratory test is a complete blood count (CBC). Among other measures, a CBC includes a microscopic evaluation of the appearance of the different red and white blood cells found in the specimen. The differential white cell count reports the relative proportion of each type of white blood cell. Although differentials are now typically performed by automated instruments, a manual differential is necessary when the distribution of the various cell types does not fall within expected or normal criteria. A manual differential consists of examining a stained smear of peripheral blood under the microscope, where one hundred white blood cells are counted and identified. Red blood cell and platelet appearance (e.g., morphology) may also be examined. Because differential results can play a vital role in the diagnosis and treatment of a patient, accurate cell identification is critical.

Visual Aids in the Clinical Laboratory

Identification of the Problem

In a recent New England Journal of Medicine editorial, R.S. Schwartz said, "Today, regrettably, many hematologists have little time to practice the art of examining the blood smear (1)". Indeed, many generalist CLSs lack proficiency in identifying abnormal cells. This lack of proficiency results from two main factors. First, as a result of continually shifting among different departments, a generalist struggles to develop sufficient depth in any one department. Secondly, due to advances in technology, automated hematology instruments have decreased the need for frequent manual differentials. Newer instruments are able to perform most normal differentials but not abnormal differentials. Thus, generalists have less practice reading differentials and, when manual differentials are necessary, they typically involve abnormal cells that are a challenge to identify.

Current Solutions

Laboratory staff usually address their lack of proficiency with traditional resources that assist with cell identification and result reporting, most notably printed hematology reference atlases and textbooks. Consulting fellow CLS staff is another method of correctly identifying unknown cells. Leaving an unknown slide for review by a pathologist or hematology specialist is yet another method of correctly identifying cells.

The newest resource that has emerged in recent years, and the focus of this literature review, is the computerized hematology atlas. Stand-alone atlases, not dependent upon a textbook or printed atlas, were reviewed. At least 9 such tools, in CD-ROM format, have been developed since 1995, a few with second and third editions

(2,3). Not all of these atlases are still available on the market, but are nevertheless reviewed because they may still be in use. Other forms of computerized hematology software (for example *Peripheral Blood-Tutor* (4), a computerized hematology tutorial) are not reviewed here because it was not felt to be a stand-alone atlas. A list of the 9 reviewed computerized hematology atlases is as follows:

1. **Hematography I An Instructional Program in Blood Smear Examination and Normal Hematology Morphology.** Lofsness K. 1996.

Hematography II an Instructional Program in Morphologic Alteration of Blood Cells. Lofsness K. 1997.

Hematography Plus an Instructional Program and Atlas of Blood and Bone Marrow Morphology. Lofsness K. 2000.

2. **Hematology: A CD-ROM Atlas with Concept Applications.** Anderson S. Version 1.0, 1996.

Anderson's Electronic Atlas of Hematology. Anderson S. and Poulsen K. Version 2.0, 2002.

3. **Interactive Haematology Imagebank with Self Assessment.** Bain B. 1999.

4. **Atlas of Hematology CD-ROM.** Cohen A., Cycowitz Z., Djaldetti M. and Polliack A. 1998. (Also titled **Encyclopedia of Haematology**)

5. **HemoSurf: An Interactive Hematology Atlas.** Woermann U., Montandon M. and Tobler A. Version 1.0, 1998. (CD-ROM or On-line subscription)

HemoSurf: An Interactive Hematology Atlas. Woermann U., Montandon M. and Tobler A. Version 2.0, 2000. (CD-ROM or On-line subscription)

HemoSurf: An Interactive Hematology Atlas. Woermann U., Montandon M. and Tobler A. Version 2.5, 2002. (CD-ROM or On-line subscription)

6. **Laboratory Hematology CD-ROM.** American Society for Clinical Laboratory Science. 2001.

7. **Atlas of Blood Cell Differentiation: Interactive Reference on CD-ROM.** Cillessen F. and Van der Meer W. 1st edition 1996.

Atlas of Blood Cell Differentiation: Interactive Reference on CD-ROM.
Cillessen F. and Van der Meer W. 2nd edition 1998.

8. **CD-ATLAS Clinical Haematology.** Hoffbrand A. and Pettit J. 1996.
9. **Hemavid.** Beck W. 1995.

As a group, these atlases have a wide range of target audiences, from a narrow audience of only students, to a broad audience of physicians, physician assistants, teachers, students and laboratory personnel. The image collections are also quite diverse. For example, one atlas is limited to 100 images while another atlas offers over 3,000 images. Most of these atlases provide some form of self-assessment, including quizzes, exams, and case-studies.

Hematography I focuses on normal white blood cell morphology while *Hematography II* focuses on abnormal and immature white blood cells (5,6). *Hematography II* also contains a compare/contrast section and an exam section for differential testing proficiency (6). *Hematography Plus* combines the first two systems, and adds bone marrow morphology with expanded and updated material (7).

Hematology: A CD-ROM Atlas with Concept Applications offers two editions, each with over 900 images and 100 case studies. The first edition offers a 100 question quiz that provides immediate feedback (8). The second edition features terms linked to **Stedman's Medical Dictionary** (9). The second edition has also added a hematologic microorganism section and a comparison section of the most common cells (9).

Interactive Hematology Imagebank with Self Assessment has been divided into sections based on the target audience, of "medical students, laboratory scientists and hematologists" (1). These sections include: browse, learn, and test (self assessment)

sections (1,10). The product also has video clips of clinical procedures, data tables, and a glossary (10).

Atlas of Hematology CD-ROM is designed for “residents and specialists in hematology, hemato-oncology, cytology and histopathology” (11). The product features 600 images and a self-assessment section of 100 questions (11,12).

HemoSurf an Interactive Hematology Atlas is an interactive tutorial and atlas with more than 3,000 images of blood and bone marrow (13). HemoSurf is now in its 3rd edition and is available on CD-ROM or by online subscription (14). The tutorial section increases in difficulty as one progresses, and it provides immediate feedback to quiz questions (14). The atlas includes disease related images (e.g., megaloblastic anemia) and a laboratory technique section (e.g., how to make a peripheral blood smear).

Laboratory Hematology CD-ROM is offered by American Society for Clinical Laboratory Science (ASCLS). The CD-ROM features images of “normal and abnormal erythrocytes, leukocytes and thrombocytes” (15). The program also offers reference values for hematology tests, a laboratory technique section and searchable text (15).

Atlas of Blood Cell Differentiation: Interactive Reference on CD-ROM features bone marrow and peripheral blood cells. Both editions target a broad audience of clinical laboratory personnel, physicians, medical students, research laboratory personnel, educators and laboratory students (16,17). Edition II offers a new side-by-side feature for comparing cells (18).

CD-ATLAS Clinical Haematology is an atlas designed to be used alone or with a textbook, *Atlas of Clinical Haematology*. The atlas has over 1,230 illustrations including cell images, diagrams, graphs and other illustrations from the textbook. Information on

leukemias, genetics, clotting, growth factors and AIDS is also included (19). Additional sections feature case studies in “histology, radiology and computerized tomography” (20).

Hemavid was created for use with the “fifth edition of William S. Beck’s textbook, “Hematology” but can also be used alone (21). *Hemavid* takes a textbook-like approach by placing emphasis on disease states and cells seen in the disease states. The program contains 1,300 cell images with multiple examples of each cell type (21).

Shortcomings of Current Offerings

From the viewpoint of a working laboratory generalist, the current reference sources appear to have significant deficiencies. In the worst case, they lead to a delay in the reporting time of the differential. As a result, patient treatment may be delayed or hospital time extended. Printed hematology references are limited by the number of pictures, number of illustrations, photo quality and amount of text included. In addition, the layout of printed books is typically more suitable for the classroom than for the workplace. For example one cannot easily search the index of a book without knowing the goal of the search. Consulting fellow CLS staff is a poor use of time and can also be poorly productive. For staff in smaller laboratories, or for those working “off shifts” with few coworkers, consultation may not be an option at all. Leaving an unknown slide for a pathologist to review is typical practice during the off shifts when no one is available, but it results in a delay of hours or even days in reporting. To be sure, certain slides must always be reviewed in accordance with criteria set by the laboratory. Nevertheless, a more efficient reference resource would allow the review criteria to change or a

preliminary report to be provided, thus significantly reducing the delay in reporting a correct, complete differential.

Computerized atlases, due to their design, have limited usefulness in the laboratory. (The term “design” used in this paper is an overall term relating to the storyboard of the atlas. This includes the sections used in the atlas, screens used, order of the screens, navigation through the screens and the aesthetic qualities of the atlas.) When reviewing the literature, eight out of the nine atlases appear to be excellent teaching tools and five of them provide some form of self-assessment. They all have clearly been designed as instructional aids.

A major problem, however, is that the design of instructional aids is too “bulky” and poorly organized for the clinical laboratory workplace. These atlases provide excess information in the form of content and self-assessments that is not needed in the workplace. Clinical laboratory scientists are already educated and certified, therefore no longer requiring training on basic hematology content and/or techniques. Yet, CLSs do need assistance in reading and reporting abnormal differentials. Also, these instructional aids are organized efficiently for students but not optimally organized or navigable for the workplace. The main deficiency of these current atlases is that they have been created as instructional aids rather than as job aids.

A job aid has been defined as “a repository for information, processes, or perspectives that is external to the individual and that supports work and activity by directing, guiding, and enlightening performance” (22). Job aids are useful when there is insufficient skill and/or knowledge. Job aids contain pertinent information that may be rather complicated or hard to memorize, yet must be available when needed (23,24). Job

aids are used when the task is infrequent, the task is challenging and “consequences of error are high” (25,26).

Job aids have many benefits for the employer as well as employees. “Job aids diminish reliance on memory” or errors that can result from incorrect memory, while supplying consistency to the task (22,23). Therefore, job aids would be very helpful for newly hired staff and/or less skilled staff. Job aids also guide decision making, perspectives and self-evaluation (25). Finally job aids save money and time by reducing the need for costly training sessions (22, 24). Simply stated, “Job aids, as personal support systems that are close at hand, help people to do their work better and to feel better about their work” (22).

Job aids exist in many formats such as a laminated card for CPR procedures, a simple set of directions displayed on a self-serve gasoline pump, or a lengthy and complex preflight checklist for an airline pilot (23,26). Job aids can be presented in multiple formats but it must be optimized for the environment and task. To determine the best format of a job aid, one must consider who will be using the job aid, whether the user is experienced with the job aid format, and the working environment where for the job aid will be used (22).

Technology has provided a new format for job aids other than printed material. Computerized job aids such as computerized applications, on-line help systems, intranet sites, or even the directions on a photocopier, are common in most work environments (27). Computerized job aids allow for interactivity, guidance and feedback (27).

Job aids have a close connection with instruction but instruction involves “presentation, practice and feedback” (22). “Even though job aids are not designed to

foster learning, it is likely that people will learn from these aids” (27). Since job aids are not instructional in purpose, any learning from them would be incidental learning (23). Incidental learning has been defined as a “spontaneous action or transaction, the intention of which is task accomplishment, but which serendipitously increases particular knowledge, skills or understanding” (28).

Incidental learning occurs in our everyday activities, although few of us are conscious of it (29). More workplace learning is being studied because of new demands by the ever changing work environment (30). Job aids promote incidental learning, which promotes advances in the workplace by helping people to do and feel better about their jobs.

There is a close connection between job aids and instruction, yet instruction is not considered a job aid. “Instruction usually happens before a need arises and builds the capacity of the individual” and prepares people to act (22). Whereas job aids “direct more immediate performance” of the individual and come “into play when a person is faced with an immediate challenge” (22). Using this criteria, a job aid, not an instructional aid, would be optimal for the laboratory to assist in identifying abnormal cells.

A Better Solution

A new solution was developed to address generalist CLSs' lack of proficiency in correctly reading abnormal differentials. The project involved the creation of a computerized job aid for CLSs in the form of a searchable computerized atlas of peripheral blood smears. This application has been designed to be placed at the workstation allowing easy access for generalists in hematology, with a large collection of images and powerful search capabilities.

The application was unique in comparison to existing tools because it was designed specifically as a job aid for the working laboratory staff. It was categorized as a computerized job aid because it stores information, makes it accessible when needed (no need to memorize), supports the work, and guides performance. Also, this tool emphasizes more powerful search capabilities than current tools. These capabilities include the use of an index and table of contents plus an even more practical ability to search by keyword and through a unique cell-feature search.

Ideally this tool would be most useful at smaller hospitals or during short-staffed shifts (evenings, weekends, and holidays). The tool should be primarily used when a CLS encounters a cell which cannot be identified while performing a differential. The user will move from the microscope to a neighboring computer, open the tool, and choose from a variety of search options, which will guide the user to the identification of the unknown cell.

Methods and Materials

Needs assessment

A needs assessment was performed to determine if professionals agreed that there was a need for such a program. The needs assessment also helped to determine the format for presentation of this product to its intended audience.

The primary survey sample was a convenience group of hematology specialists and supervisors in diverse regions of the U.S. who participate in an electronic discussion group devoted to hematology topics. A secondary survey sample consisted of staff members working with the primary sample subjects. The group of seventy-one specialists/supervisors was initially emailed with an invitation to participate in the survey. Of the seventeen responses, sixteen agreed to participate in the survey.

The needs assessment began with the design of a questionnaire survey. The survey consisted of questions regarding the laboratory equipment, background of the participant, types of available computers, and aspects of the proposed program. The original questionnaire was divided into two separate questionnaires for the primary and secondary subjects in order to avoid repetition of laboratory and departmental questions. Therefore, one survey was designed for the hematology specialist/supervisor and contained a section specifically relating to their laboratory and department. Staff surveys omitted these same laboratory and department questions. An introductory letter stated the purpose of the needs assessment, a statement of confidentiality and instructions for the questionnaire. The specialist/supervisor questionnaire, staff questionnaire and introductory letter are found in Appendix A. All the documents were approved in

advance by the University Committee on Research Involving Human Subjects (UCRIHS).

The sixteen participants were mailed, either electronically or via postal service, packets containing specialist/supervisors questionnaires, staff questionnaires, the introductory letter and mock screens of the proposed program. Participants were requested to distribute the surveys to their staff and return them within two weeks.

Of the sixteen volunteers, eight returned packets (only seven were usable), for a return rate of fifty percent of volunteers. (The unusable packet consisted of a specialist/supervisor survey with comments in the comment section but no survey questions answered.) Of eight packets, nine specialist/supervisor surveys were returned (one packet contained two completed specialist/supervisor surveys) and thirty-three staff surveys were returned.

Image Collection, Acquisition and Editing

Image collection began by locating peripheral blood smears with exceptional examples of cells. (An exceptional example is not necessarily the “classic” cell but could be an adequate cell from a well-preserved slide.) From hundreds of such slides in the Michigan State University (MSU) Medical Technology Program collection and in other private collections, more than one hundred slides were selected for photography.

Photographs were made using an Olympus BH-2 microscope with a 100x objective, a Nikon Digital DMX 1200 camera and Nikon ACT1 Version 2.00 software. The equipment was located at Ferris State University, Big Rapids, MI, and was used with permission and assistance of Mr. John Landis, Clinical Laboratory Sciences Program. Images were collected and saved in a 3200 x 2560 pixel JPEG (Joint Photographic

Experts Group) format for best resolution. Multiple exposures of the same cell were often photographed under different light intensity or position.

Editing the images was accomplished with Adobe® Photoshop® 5.5. Slide debris was removed from each image, followed by cropping. Images were resized to 600 x 400 pixels to fit a typical computer screen. When multiple cell types were present, arrows were added in order to emphasize one distinct cell of interest. The edited images were reviewed for accurate identification by Kathy Doig, PhD, CLS(NCA).

Focus Group: Program Questions

The computer program is distinctive in its use of a unique cell-feature search. The search begins with seven categories to which an unknown cell might belong. The first category is for unknown nucleated cells, white or red blood cell series, when the user has no other information. If selected, this category presents a series of questions regarding the unknown cell. The responses will lead to a selection of images, one of which should match the unknown cell.

The formation of the questions to be used in the cell-feature search began in a focus group that included seven clinical laboratory scientists with varying experience in hematology. The focus group was also referred to as “The Meeting of the Minds”. The group was presented with a draft of questions that might be used in the program. Many ideas were put forth and considered in the design of the questions. Topics of discussion included the number of questions and the phrasing of questions that focused on color (e.g., cytoplasm color).

Database

The database is the heart of the program, and contains essentially all the content used in the program, including the text, image filenames and the words used in the searches. The database was made using Microsoft[®] Excel. The content in the database was based on the images taken, the author's prior knowledge, hematology textbooks and atlases. Several drafts of the database were made leading to the completion of a large, complex database. The database was reviewed for content accuracy by Kathy Doig, PhD, CLS(NCA).

Design Phase

The design of the program refers to the interface that enables users to access information and images from the database. The design process began with the creation of a flowchart to visualize the navigation of the atlas. The flowchart illustrates the main screens and the logic of navigation used in the atlas. The flowchart was produced using Microsoft[®] PowerPoint[®].

A detailed storyboard was created from the flowchart to serve as a visual representation of the atlas. The storyboard consisted of a sketch of each screen in the atlas and details about the text, buttons, graphics and other details about the screen. Creation of the screens used in the storyboard was a collaboration of the focus group, guidance committee members and project consultants. Once a detailed storyboard was finished the process of building the program began.

Building the Program

The guidance committee carefully considered the media software selected to build the program and Macromedia Director[®] 8.5 Shockwave Studio was chosen.

Macromedia Director[®] is an integrating program; “its primary purpose is to bring a number of different kinds of elements into one package” (31). Macromedia Director[®] is presented in a theatrical manner using corresponding terminology such as “stage”, “score”, “cast members” and “script”.

The author received training on Macromedia Director[®] from Brian Winn, MS, Assistant Professor, MSU Department of Telecommunication and also from *Director 8 and Lingo Bible* and *Macromedia Director[®] 8.5 online help*. The building of the program began with a template made in Macromedia Director[®]. The screens (frames) were assigned a name and ordered. Simple navigation buttons were added to each frame using Macromedia Directors’[®] built-in options or with simple programming using Macromedia Directors’[®] scripting language of Lingo. Short, simple text (e.g., instructions) was then added to the current screens.

The template consisted of basic program screens that were based on the storyboard. The major building block templates included: formatting the database for Macromedia Director[®] and merging it into the Macromedia Director[®] file; downloading the JPEG images; downloading or adding text to the screens; programming Macromedia Director[®] to interface with the database for searches; programming Macromedia Director[®] for navigation and appearance of the template; testing the database interface for accurate performance; and lastly, improving the look, navigation and ease of use of the template. This resulted in a functional template that was copied to multiple CD-ROMs for pilot testing.

Pilot Testing

Pilot testing is defined as the “process whereby the developer tries out the job aid with ‘real world’ end users” (22). The first step was to establish a test group. Since the participants of the needs assessment and “meeting of the minds” were already aware of the project, these two groups were selected as the test group. Again, letters or emails were sent inviting these original group members to participate in the pilot test.

Out of the seven original participating hospitals of the needs assessment only four agreed to participate. Of the original seven focus group participants (excluding guidance committee members) only three agreed to participate in the pilot test. The guidance committee decided that smaller hospitals were not strongly represented within these two groups. Therefore, additional hospitals were contacted, and four agreed to participate.

An evaluation form was designed to accompany the CD-ROM. The evaluation focused on the usefulness of the job aid with a rating section and question section. A copy of the evaluation form is found in Appendix B. An introductory letter stated the purpose of the pilot test, and included a confidentiality statement and instructions for use. This letter and the evaluation form were also submitted to and approved by UCRIHS.

All participants of the pilot test received packets including an introductory letter, a flyer for staff personnel, an evaluation form, instructions for using the CD-ROM and the pilot test CD-ROM. Participants had one month to complete the pilot test.

Of the eight volunteers (supervisors at four participating hospitals of the needs assessment and four smaller hospitals) seven returned completed evaluation forms, for a return rate of eighty-eight percent. Of the three participating focus group members, three returned completed evaluation forms, for a return rate of one-hundred percent. From

these two groups of participants a total of thirty-three evaluation forms were returned.

The results and comments obtained from the evaluation forms were gathered and reviewed. This data resulted in changes made to improve the atlas. Most of the suggested changes involved navigation and aesthetic aspects of the atlas.

Results

Needs assessment

The results, as presented in Table 1, clearly demonstrated that the clinical laboratory scientists who were surveyed perceived a need for better peripheral blood smear identification resources and that the proposed program would be beneficial to their laboratory.

Table 1 – Needs assessment significant results.

	Yes	No	No Answer
Need for better hematology resources	31	6	5
Proposed program will be beneficial	38	1	3

The surveys asked one question pertinent to the content of the atlas, “Which two cells are the most difficult for you to identify when performing manual differentials?” The results to this question are presented in Figure 1, confirming my initial suspicion that blasts (immature white blood cells) are one of the most difficult cells to identify with accuracy and confidence. This information was used in the consideration of the program content and ensured that numerous images of immature white blood cells would be in the atlas.

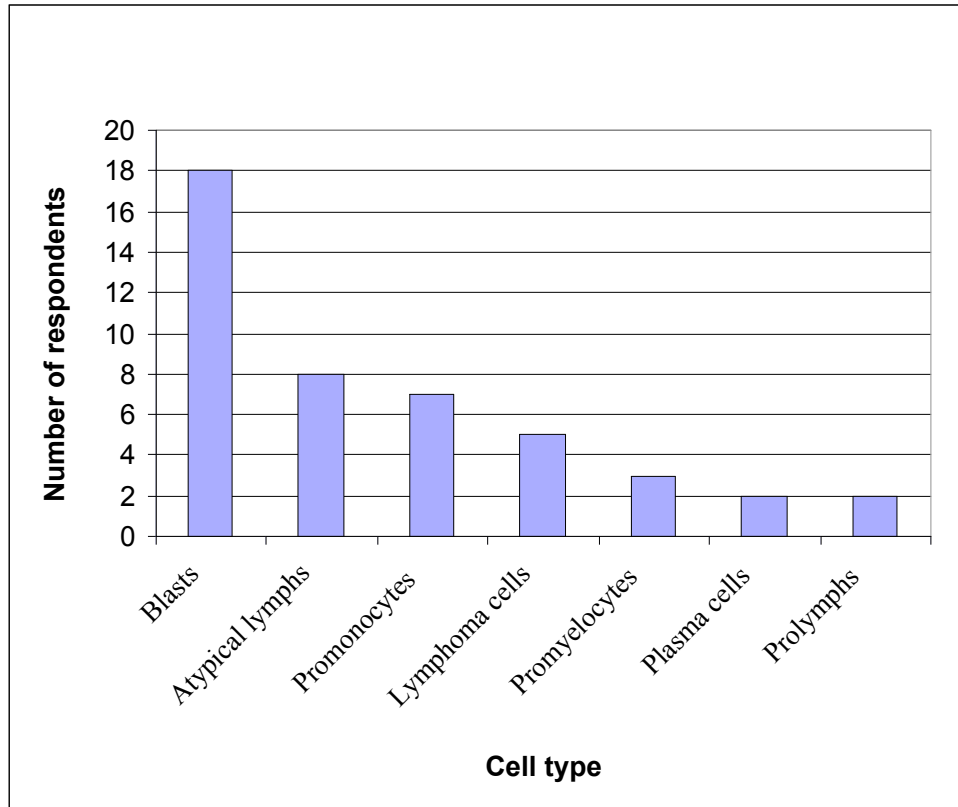


Figure 1 – Number of respondents identifying cells that are most difficult to identify when performing manual differentials.

The survey results also indicated that the project should be presented as a CD-ROM rather than as a web based application. Most of the participating laboratories reported that they do not have internet access. These data were similar to the general consensus of the guidance committee that a significant number of hospital laboratories are not internet accessible at this time.

Image Collection, Acquisition and Editing

A total of 673 images were initially prepared. Images were selected for best quality and then edited. A total of 192 images were selected for use in the atlas.

Focus Group: Program Questions

The suggestions and ideas from the “meeting of the minds” produced a new draft of questions. Revised questions were shorter, with fewer choices, and color choices were discarded due to the requirement for subjective judgement on the part of the viewer. A total of four questions were selected for the cell-feature search.

Database

The database is essentially a table with rows and columns. Each database row represents one cell type or feature (for example: monocyte, dacryocyte or basophilic stippling). Database columns are of two categories. The first is for columns that contain the information on which the searches are based, such as: Image Filename, Cell Name, Synonym/Abbreviations, Cell Line, Nucleated/Non Nucleated, Nucleus Percent, Nucleus Shape, Nucleoli Seen, Granule Series, Inclusion/Shape, Projection/No Projections and Keywords/Misspellings. The second category of columns contains the text that appears below the image in the program, such as: Cell Name, Image Size, Synonym/Abbreviations, Cell Size, N/C Ratio, Nucleus Position, Nucleus Shape, Nucleoli, Chromatin, Cytoplasm Color, Granules, Granule Distribution, Granule Size, Inclusion Shape, Inclusion Color, Number Per Cell, Composition, Classic Peripheral Blood Description, Associated With and Editorial Comments.

Design Phase

A copy of the flowchart and a portion of the storyboard created in the design phase and used in the building of the program are found in Appendix C.

Building the Program

Refer to the accompanying CD-ROM.

Pilot Testing

The returned evaluation forms contained generally positive comments. It appeared that the most useful and positive evaluation forms were from smaller hospitals, which was the intended target audience. The evaluation forms were divided into three sections (rating scale section, short question section, and a comment section). The responses are presented in Tables 2, 3 and 4 with the action taken on the feedback provided. Fifty-five percent of pilot test participants used the atlas once, thirty-nine percent used the atlas two to four times and six percent used the atlas over ten times.

Table 2 – Results of rating scale for navigation and interface of the atlas.

Query	Poor	Adequate	Excellent	No Answer	Action Taken
Speed of program	1	15	17	0	No action taken
Ease of navigation	1	21	11	0	Modified
Function of buttons	3	19	10	1	Modified
Quality of images	1	16	15	1	No action taken
Number of images	2	23	8	0	Future goal
Clarity of instructions	1	23	9	0	Modified
Amount of text	2	24	6	1	No action taken
Readability of text font	1	15	16	1	Modified
Helpfulness of zoom	0	6	26	1	No action taken
Usefulness of cell search	8	15	9	1	No action taken

Table 3 – Short questions regarding features and shortcomings of the atlas.

	Yes	No	No Answer	Action Taken
Job aid convenient at workstation	24	8	1	No action taken
Easily answer questions in cell-feature search	28	5	0	No action taken
Finding of cells not covered in the atlas	17	12	4	Future goal
Errors in the atlas (buttons, text)	12	20	1	Modified
Addition of disease states	30	2	1	Future goal
Addition of compare section	30	1	2	Added to atlas
Desire for copy of the atlas	25	6	2	No action taken

Table 4 - Cumulative hand-written evaluator comments.

Comments	Responses	Action Taken
Great potential, demand for, user-friendly	6	No action taken
Ample number and high quality images	3	No action taken
Ideal for students	3	No action taken
Addition of disease states	3	Future goal
Addition of case studies, special stains, microorganisms	3	No action taken
Addition of compare section	2	Added to atlas
Addition of unavailable images	2	Future goal
Keyword instructions	2	Modified
Useful zoom feature	2	No action taken
Cell-feature too broad	1	No action taken
Overlap of images on image selection screen	1	Modified
Poor quality of images	1	No action taken
Blasts not defined by lineage	1	No action taken
Allow laboratories to submit images	1	No action taken
Adequate quality and quantity of text	1	No action taken

Atlas Improvements Based Upon Pilot Testing

The results and comments received from the pilot test were used to improve the atlas. The first major change was to create a familiar interface for the atlas to make it more appealing and user-friendly. Therefore the atlas was changed to resemble a Microsoft® Windows® application with changes such as the addition of a title bar and menu bar. (Improving the interface was a goal before pilot testing, however due to time constraints this was not accomplished, therefore pilot test results did not largely contribute to this improvement.)

The next major change in the atlas was to incorporate a section for comparing two images side-by-side. However, in order to add the comparison section, the flow and navigation needed to be improved. The atlas was changed from using non-defined, non-sectioned search and view screens to defined sections of search, view and compare. The comparison option operates by selecting two images and placing them into the “compare” category. The compare screen allows users to view two selected images from current or previous searches simultaneously.

The last major change allows users to select images from previous searches for use in the comparison section. This was accomplished by creating a “history of searches”. The atlas will automatically save and label each search as it is performed including the search criteria used (answers to questions). This will allow users to view or edit search criteria without starting a new search.

Minor changes were also made to the atlas such as the addition of shortcut keys (keys pressed on the keyboard to complete a task). These changes were made to create a professional, innovative product. All of the changes were intended to simplify the atlas yet at the same time give the users more features.

Discussion

White blood cell differentials play an important role in the diagnosis and treatment of patients, demanding results that are both fast and accurate. Yet, the profession faces the challenge of generalist CLSs who may lack proficiency in identifying abnormal cells on peripheral blood smears. This project addressed the challenge by creating a computerized atlas as a job aid for generalist CLSs to use while performing a manual white blood cell differential.

Advantages of the Program

The advantages of this computerized atlas are numerous in comparison to current computerized atlases. First, the atlas is designed as a job aid and not as an educational aid, therefore shifting the target audience to the certified CLS working in the lab. The result is an atlas offering a straightforward resource for performing white blood cell differentials without cumbersome and unnecessary instructional features such as self-assessments.

The atlas offers a unique method of searching for a cell image, the cell-feature search. This search offers seven categories ranging from a cell-line category (e.g., white blood cell - granulocytic line) to a category of unknown lineage (unknown nucleated cell). These categories lead the user directly to an image selection or to a screen of question(s) to narrow the search based on features of the cell. For example, the unknown nucleated cell category presents the user with four questions pertaining to the characteristics of the cell they are trying to identify. The answers selected to these four questions will present a selection of images that most closely matches the specified cell

characteristics. Once a closely matched cell has been selected, the user is presented with a larger image of that cell, accompanied by pertinent text about the cell.

Besides the cell-feature search, the atlas offers three other methods for finding an image of a cell: a keyword search, similar to internet search engines, plus two more traditional search methods, namely the table of contents and an index.

An interesting feature of the atlas is the ability to compare images. The atlas has a section in which two selected images can be compared on the same screen. The user has multiple options to select an image and can use images from their current or previous searches.

Another feature of the atlas is its ability to keep an ongoing history of searches. This section allows users to view past and current searches. Not only will users be able to view their past searches, they can also change the search criteria and repeat the search using the new criteria. This option is also useful for comparing of images.

These advantages, plus others, make the atlas a new, unique hematology reference. Together, these advantages add to the overall appeal and usefulness of the atlas in the workplace.

Unmet Challenges

As with any new product, many challenges arose during the creation of the product. Many of these challenges were overcome, but due to various reasons a few of these challenges remain.

The first unmet challenge is that images are not labeled or accessed by an associated disease state. Initially, the guidance committee agreed that disease state images would not be incorporated into the atlas due to their lack of usefulness. Yet, the

majority of pilot test participants responded that disease-state classified images would be an asset to the atlas (see Table 3).

A second challenge is to consider the addition of more images. Although initially 673 images were taken, only 192 of these were actually used in the atlas. Many cell types have multiple images but a few only have one image available, and some desired cell examples were not found within the slide collections made available. A comprehensive atlas should perhaps offer multiple images of every cell type. Current atlas collections (reviewed in the Introduction) range from 100 to over 3000 images, so this atlas is among the smallest. The author can add images to the program in the future.

Another challenge is to improve the cell-feature search. As indicated in Table 2, the usefulness of the cell-feature search received a “poor” rating from twenty-four percent of respondents. No action was taken to improve this option because seventy-three percent of pilot test participants found the usefulness of the cell-feature search adequate or excellent (three percent did not answer). However, due to the ratings received, the questions likely need to be re-evaluated and improved.

The final challenge is the lack of small hospital representation in the pilot test. Since smaller hospitals and short-staffed shifts are the ideal target audience for the atlas, more feedback from this population was desired. This would have helped ensure that the atlas will address the needs of generalist CLSs working in small hospitals and/or during short-staffed shifts.

Advice for Future Atlas Projects

Several suggestions can be provided for those who may be considering a similar project. First, brainstorming sessions with one or more colleagues will provide valuable

new perspectives for creating the layout and content of the program. Take all perspectives into consideration before finalizing any ideas.

Investing time and effort in a detailed storyboard of the layout, content and navigation will save time and frustration later in the process. A detailed storyboard is the compass through the creation process. Not only will it keep the author on track but also it is an easy tool for others to follow and offer advice.

Use Macromedia Director[®] (latest version) for building the program.

Macromedia Director[®] may be difficult at first, but understanding of the program opens up limitless design opportunities. Macromedia Director[®] can be used to create motion media, games, web pages and many other forms of multimedia applications.

Macromedia Director[®] is only limited by one's imagination, creativity and ability to program with *Lingo*.

Regarding *Lingo*, one must be either be proficient in programming or hire a programmer. Programming is the key to any successful, user-friendly computerized application. Creation of easy navigation tools, accessing the database and creating an attractive, interactive interface are all accomplished with programming.

Summary

The goal of this project was to create an improved hematology computerized atlas with search options as a job aid for practicing laboratory professionals. This goal has been accomplished. The computerized atlas has many advantages over previous computerized atlases. The atlas has proven functional in the laboratory based on a pilot test. The design of the atlas also offers multiple search options to guide users in a simple,

logical format. Although the atlas does not contain an exhaustive collection of images and content, this was not a principal goal.

Future expansion is as yet undetermined. The foremost goal would be to add disease states to the atlas. Based upon needs assessment comments, the addition of bone marrow images would also be an enhancement to the atlas.

APPENDICES

APPENDIX A

Needs Assessment: Specialist/Supervisor Questionnaire, Staff Questionnaire, and
Introduction Letter

APPENDIX B

Evaluation Form for Pilot Testing

APPENDIX C

Organizational Chart Used in the Building of the Program

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