Turning Expertise into Instructional Excellence: Essays for Cytotechnology Educators

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This is an example of an organizational structure, given prior to more detailed discussion. This "cognitive framework" or ***advance organizer*** assists learners in organizing content so that they may learn it more easily.

Advance Organizer: This series of essays is designed as a means of providing some educational concepts and background as well as practical tools for instruction so that we may improve the quality of the educational process for cytotechnology students. Many of these ideas may be ones you have already implemented. Some may be new to you. But they at least provide a framework for the difficult task of turning beginning students into highly skilled professionals in the cytology laboratory. The content is as follows:

Introduction

Marilee Means, Ph.D., SCT(ASCP)

Every year, when we interview prospective students for our Cytotechnology Program, we ask what turns out to be a very instructional question for all of us:

Describe the teaching style of your favorite college instructor.

Almost universally, in a moment, there are enthusiastic answers. Phrases such as "hands on," "knows how to involve the students," "makes it easy to understand," "depth of knowledge," and "uses methods besides just lectures" are frequent.

If we think about our own least effective teachers in college, often we can recall a highly educated, talented researcher type, who obviously knew the subject matter well, but who had little success explaining basic concepts to students. I remember a chemistry professor, having given a textbook definition of some basic concept, was asked to further explain. His response? He repeated his previous statement word for word. A humanities professor, fluent in five languages, was teaching world literature. As one of two questions on a midterm, he asked, "What is the one word which describes the main character's logic in Act III of Moliere's play? Hint: It is not a word you would run across in a month of Sundays." Never once mentioned during lecture, the word "casuistry" is indelibly stamped in my mind. Of course, my 50% score on the test is also remembered less than fondly, as is the be-speckled professor who chuckled because the entire class missed the question. No doubt all of us have both fond memories of terrific teachers and horror stories of those who were, quite frankly, terrible.

As we all aspire to improve the caliber of our instruction, we need to look not so much at our fund of knowledge in cytotechnology (although of course we are all constantly updating and refining that resource) but we also need to examine how we teach. Remember those college professors who must have known the definition of Avagadro's number but were powerless to explain it to a student? This is why these essays are entitled **"Turning Expertise into Instructional Excellence."**

This series of essays is meant to specifically address not so much the content of cytotechnology education, but more the basic educational concepts of how we learn, what teachers can do to assist learning, how we can involve students in their own learning, how good teachers are made not born, and various methods of lecture, discussion, assignments and other tools for cytotechnology education.

Turning your expertise and experience into excellent instruction in our programs is the best contribution we can all make to the future of cytotechnology, no matter where the future takes us, no matter what content we teach.

Advance Organizer: This essay discusses a prominent learning theory, the *cognitive approach*. It posits that students must create their own meaning as they are presented with new information. As they assimilate the new knowledge, they adjust and refine their understanding of the topic. As instructors, there are several methods we can use to enhance this creation of meaning. These methods have been shown to increase understanding and retention of knowledge.

How Do We Learn?: Cognitive Theory and Its Implications

Marilee Means, Ph.D., SCT(ASCP)

Many theories regarding the nature of how learning occurs have been put forth over the years. Psychologists and educators, especially, have been interested in this topic. We will discuss one theory that has a great deal of relevance to cytotechnology education, cognitive theory.

We are all familiar with the surprising (to us) performance of a class on a question whose content was carefully explained in the lecture. "But I told them that!" we sigh to ourselves and our colleagues.

Tip #1: Telling is not teaching.

Remember that, to a student unfamiliar with the subject matter (as are most beginning cytotechnology students), our careful explanations and detailed lectures may be as meaningful as waves crashing on the beach. Without a framework of understanding, the jargon-laden lecture may not lead to understanding. The "teaching" part means not only "telling" but also designing some kind of supporting tools or strategies to help the student make associations with previously learned material, or make connections with a well understood analogous situation. It can be aided by having students make a table, a chart, a drawing, or a flowchart that requires them to create meaning for themselves, thereby enhancing both understanding and memory.

This concept is quite useful, especially for college-aged students learning complex material. This cognitive approach has several basic areas of focus. Learners "construct" meaning as they meet new information and attempt to fit it into previously learned material. Cognitive theorists speak of mental "frameworks," which the student builds and to which they attach new information as their knowledge increases. (For an example of a type of "framework," note the examples of an ***advance organizer*** at the beginning of each essay.) Good instructional techniques can facilitate the students building these frameworks. For additional information on cognitive theory in college teaching, see Bruning (1994) [1] and Cassazoa and Silverman (1996).[2]

Svinicki (1991)[3] makes the following six points concerning the principles of learning based on cognitive theory and correlating implications for instruction.

1. If information is to be learned, it must first be recognized as important.
Implication: the more attention is effectively directed toward what is to be learned (that is, toward critical concepts and major areas), the higher the probability of learning...

2. During learning, learners act on information in ways that make it more meaningful.
Implication: both instructor and student should use examples, images, elaborations, and connections to prior knowledge to increase the meaningfulness of information...

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[1] Bruning, R. H. (1994) The college classroom from the prospective of cognitive psychology. In K. Prichard & R. Sawyer, (Eds.) *Handbook of college teaching* (pp. 3-22). Westport, C: Greenwood Press.
[2] Casazza, M.E., & Silverman, S. L. (1996). *Learning assistance and developmental education*. San Francisco: Jossey-Bass.
[3] Svinivki. M.D. (April, 1994). Lecture handout: Teaching with the Learner in Mind. Office of Faculty and TA Development, The Ohio State University.

3. Learners store information in long-term memory in an organized fashion related to their existing understanding of the world.
Implication: the instructor can facilitate the organization of new materials by providing an organizational structure, particularly one with which students are familiar, or by encouraging students to create such structures...

4. Learners continually check understanding, which results in refinement and revision of what is retained.
Implication: opportunities for checking and diagnosis aid learning…

5. Transfer of learning to new contexts is not automatic but results from exposure to multiple applications.
Implication: provision must be made during initial learning for later transfer…

6. Learning is facilitated when learners are aware of their learning strategies and monitor their use.
Implication: the instructor should help students learn how to translate these strategies into action at appropriate points in their learning…

Some suggestions for cytotechnology educators based on these principles are as follows:

1. Focus on what is important.
Spend the most time/effort/attention on the most important topics. While it is obvious to us what these are, it is not obvious to the student. For example, an extensive laundry list of all possible organisms in the gynecologic tract can be overwhelming to the beginning student. Emphasize them according to their frequency or importance. All students must be thoroughly familiar with *Trichomonas vaginalis, Candida albicans, and Herpes simplex*, for example, while *alternaria* is less important in the scheme of things. Let the students know this up front. It will help their studying and their understanding of the topic.

2. Act on information to make it meaningful.
One can always try to make associations to things the students already know or to previous coursework knowledge. For example, the process of squamous metaplasia as a benign protective reaction is more completely and quickly understood by comparing it to other benign protective reactions in the body such as the formation of a callus on one's heel.

3. Facilitate organizational structure to help students build mental frameworks.
Try explaining the overall spectrum of neoplastic changes and their criteria before taking up ASCUS, LGSIL, HGSIL, and cancer in turn. In other words, explain how in general, the nuclear/cytoplasmic ratio increases because as the cells get smaller, the nucleus tends to get larger as the degree of abnormality increases. Discuss the various chromatin patterns from vesicular nuclei in normal cells to irregular clearing and clumping in cancer. Note how, in the spectrum of neoplastic changes, the cells tend to become more and more disassociated and disorderly. Revealing all of these criteria at once in a simplified version will assist the student when they later take up each diagnostic entity in turn. This is another type of advance organizer.

4. Frequently check understanding.
Checking learning can be as simple as pausing frequently to ask if there are any questions to as complex as having the student describe at the microscope their reasons for a particular diagnosis. Sometimes students have difficulty in initially learning the correct criteria (i.e. they don't know the chromatin pattern associated with CIS), or they do know the "words" but they are having problems seeing the pattern and recognizing that it represents a certain entity. They might look at salt-and-pepper chromatin but misinterpret it as degeneration with karyorrhexis. It is obviously very important to determine which problem it is so it can be remedied.

5. Assist in transfer of learning.
It is helpful, for example, when teaching the characteristics of apocrine metaplasia in the breast, to note that this cell type will also appear later in the course when studying thyroid (Hurthle cells) and salivary

gland (oncocytes). Preparing students for this transfer of learning makes the actual process easier at the appropriate time.

6. Help students become aware of their learning strategies.
An especially good exploration of this can occur at the multi-headed microscope as students discuss not only what their diagnosis is but also how they arrived at it. One student may want to rule out other diagnoses first. "It's not repair because the cells are disassociated. It's not dysplastic because there are prominent nucleoli," etc. Another may select the most obvious diagnostic feature and then keep refining down to the correct answer. Helping students learn their best diagnostic strategies is very effective.

Active involvement in learning is also quite a powerful tool as it also helps the student build meaning and structure in the content. This is discussed more fully in a later essay but here are some suggestions that use this concept:

1. Have the students briefly summarize their understanding either orally or in written format at the end of class.
2. Assign projects that make the student organize the topic into a chart, graph, or sketch.
3. Use an empty lecture outline that makes the student fill in as you lecture.

If we focus on what is most important, use easily understood examples and analogies, provide and promote organizational structure of content, frequently check for understanding, facilitate transfer of learning, and help students find their best diagnostic and learning strategies, we will be incorporating a very powerful research-based tool for teaching. We will be using the manner in which students learn to help create meaning, understanding and knowledge. We will have moved beyond "telling" to "teaching."

Advance Organizer: Faced with a seemingly overwhelming amount of material to teach, we may wonder what to include and what to omit. However, there are some resources to use in deciding what to include in the curriculum. These resources include our entry-level competencies, graduate and employer survey results, student performance on the registry exam, input from our communities of interest, and the profession itself. Organizing these topics into a course can be accomplished by using instructional objectives. The consideration of multiple degrees of complexity of learning can also be addressed by taking into account Bloom's taxonomy levels when developing goals and objectives for the courses. Finally, learning activities can be designed, which support the attainment of the various educational objectives specified.

What Should We Teach?: Organizing the Course

Marilee Means, Ph.D., SCT(ASCP)

Periodically, the profession considers what the basic entry-level competencies for beginning cytotechnologists should be. These were previously included in the **Standards and Guidelines** *for an Accredited Program for Cytotechnologists* (1998) but since the 2004 revision they have been included in a separate document. Our accrediting agency, the Commission on Accreditation of Allied Health Educational Programs (CAAHEP) requires that all programs meet this minimum standard of educating students to these entry level competencies. Thus, as the profession grows and changes, these competencies also change. As such, they provide an important resource for the design of the curriculum. However, these competencies are not the sole resource. Other factors also must be considered when deciding what to include in the curriculum.

For example, our programs have as their primary intent the creation of entry-level cytotechnologists. One measure of our success in this endeavor is to evaluate the graduate and employer surveys of our students after they have been working in the field for a few months. The graduate and/or the employers may well note an area of weakness in the students' preparation (thyroid FNA, evaluation of adequacy on gynecologic samples, etc.) that can be strengthened in the curriculum. Additionally, these surveys may also note curricular areas of strength, which may serve as models for other topics.

Next, the results of student performance on the registry exam are another important source for curricular improvement. While the overall results of passing or failing are obviously quite important, the subcategory results also provide very specific information as to areas of performance that can be strengthened. Particularly if one area seems low compared to the student performance in other areas, one can work towards strengthening the curriculum in that topic.

Finally, the profession itself will continue to be a source of new knowledge, will create the need for new skills, and will demand well-educated entry-level personnel who can adapt to the changing needs of the marketplace. Learning professionalism, ethics, the need for teamwork, management concepts, safety, and a host of other topics beyond just identifying malignant cells are all curricular areas, which the profession demands in its beginning cytotechnologists. Consulting with one's colleagues in the field and in our other communities of interest is also an important source of input into the curriculum.

Given all these sources of curricular topics, how do we translate them into an educational program? One way of doing this is to develop a course outline and then address the specific instructional objectives in each topic. Behaviorist theorists encouraged the use of very precise, narrow, measurable goals, which included the evaluation criteria for each goal. For example, "The student will be able to draw the anatomic structures of the female genital tract to 100% accuracy compared to the textbook."

However, since learning theory has progressed to utilizing cognitive theory, educators are more apt to take a somewhat broader approach, while avoiding objectives that are so general as to be meaningless (e.g. "The student will understand cytology.").

One useful approach is to consider Benjamin Bloom's (1956)[4] taxonomy of thinking processes. This includes increasingly more complex and abstract levels of learning. It is particularly instructive to consult these, not only when writing objectives, but also when creating tests, so that not all of our focus is simply on memorization and recall of facts. We should try to evenly distribute our objectives over the whole range of taxonomy levels. Bloom's levels include the following:

Knowledge	Primarily concerns the students' ability to memorize or recall certain specific facts. *Example: The student can define squamous metaplasia.*
Comprehension	Involves the ability to interpret, paraphrase and extrapolate, thus demonstrating the students' basic understanding of ideas that they did not originate. *Example: The student can give examples of situations that would violate HIPAA regulations.*
Application	Includes activities in which the student applies concepts and principles to new and/or practical situations. *Example: The student can identify repair cells on an unmarked slide.*
Analysis	Concerns breaking down a piece of information into its constituent parts, differentiating and discriminating. *Example: Students can evaluate a patient history and identify the most significant components as they relate to cytology.*
Synthesis	Involves the blending of elements and parts in order to form a whole. Students should be able to create a structural pattern that was not previously present. *Example: Students can create a case study by providing patient history, describing cytologic findings, selecting areas for photography, and discussing the disease process.*
Evaluation	The highest level. Students might judge the value of a work, the logical consistency of written data, or the adequacy of someone else's conclusions. *Example: Student can critically read and evaluate a research article in cytology, determining if the conclusions reached are supported by the research design and the data.*

Obviously, the higher order taxonomy levels such as application, analysis, synthesis, and evaluation are critical to our performance as cytotechnologists. However, lower order taxonomy levels are necessary building blocks for developing the course content. Thus, critically evaluating both the objectives (and their correlating test items) to assure a range of instructional levels is essential to developing a strong curriculum. The curriculum should not just focus on memorization and recall, but it also should develop the skills of diagnosis and critical thinking.

After appropriate instructional objectives have been written for each unit, one must then consider various types of learning activities. These learning activities may include the readings, the lectures and the microscopic demonstrations. However, in an attempt to provide for a variety of learning experiences, which will also benefit those who learn best by various methods, consider some of the following possibilities:

1. Participate in a small group discussion of an ethical dilemma.
2. Utilize problem-solving techniques by addressing a series of laboratory trouble shooting problems.

[4] Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives*. New York: Longmans, Green.

3. Use a CAP checklist and evaluate the lab.
4. Create a chart with drawings of infectious agents of the gynecologic tract.
5. Write up an interesting case to include cytology and histology photographs, the patient's history, the cytologic and histologic findings, and a discussion of the disease process illustrated.
6. Evaluate research articles for soundness of design, adequacy of conclusions, and adequacy of supporting data.
7. Prepare a glass slide case conference, which demonstrates a range of diseases in one site, such as thyroid.

As one plans the curriculum, it is good to keep a couple of instructional tips in mind.

Tip #2: Plan for successful un-graded practice.

Cytotechnology is a very challenging field both to practice and to teach. Always plan for opportunities for your students to practice their diagnostic skills on un-graded material prior to the actual test. If done successfully, this can reduce test anxiety, give students and instructors accurate feedback about their progress (or lack thereof), and indicate areas needing remediation before the actual test. Going over these slides at the multi-headed microscope is a prime "teachable moment" in which the students are very attentive and can learn not only from their own mistakes but also from those of others. The tone of this encounter should be supportive, encouraging, and positive.

Thus, the cytotechnology educator develops the curriculum form a variety of resources including the entry level competencies, feedback from graduate and employer surveys, registry test scores, and input from our colleagues and other communities of interest in the field. These curricular inputs are then organized into logical units or courses. Instructional objectives over a range of taxonomy levels are then written for each course. Finally, learning activities that support these objectives are planned and written into the course syllabus. By developing a well thought out plan, having specific instructional objectives in mind, and by creating supporting learning activities, the curriculum can become the strong backbone of a successful program. For an example of what this process might look like, see the following example on understanding the scientific method.

Course: Senior Seminar

Learning Objective: The student will be able to critique a research paper by evaluating the conclusions in light of the research design and supporting data.
(Derived from entry level competency - Understanding of the scientific method)

Readings: A series of research articles on HPV following the development of this research from 1976 to the present. Students will read Research Design, chapters one and two.

Learning Activity: Students will create and discuss a Vee diagram on each of the papers studied. (See Active Learning essay for more information on Vee diagrams.)

Learning Activity: Students will complete study questions and attend lecture on understanding basic statistics.

Evaluation: Students will complete a test on basic statistics and research methods. The test will include the reading and evaluation of a research paper unfamiliar to the students.

Taxonomy levels:
Knowledge - mean, standards deviation, p value, etc.
Comprehension - interpreting charts in the unfamiliar research paper
Application - using statistical data in the unfamiliar research paper to reach conclusions
Analysis - determining the hypothesis and assumptions used in the paper
Synthesis - creating a Vee diagram of the unfamiliar paper

Evaluation - determining the adequacy of the conclusions reached in the research, given the supporting data

Note that not all taxonomy levels need to be used in every course. Just be careful that complex as well as lower level taxonomies are used throughout the program and throughout the evaluation process. This example is quite abbreviated for the purposes of illustration. Most units probably will need to contain many more instructional objectives and learning activities.

Advance Organizer: Probably still the most commonly used methodology in higher education, the lecture method has been criticized on a number of levels. It is said to place the students into a passive role, to require excellent speaker skills, and to be quickly forgotten. However, it does have the ability to convey large amounts of factual material rapidly, can provide human face-to-face interaction, and can convey the speaker's enthusiasm for the subject better than other methods. How can we build on the strengths of the lecture method and mitigate its weaknesses?

The Much Maligned Lecture: Ideas for Improvement

Marilee Means, Ph.D., SCT(ASCP)

The lecture approach to the delivery of course content has a number of strengths and weaknesses which are discussed in detail in "Teaching at the Ohio State University: A Handbook", 4th rev. ed., 1997. To paraphrase:

Strengths

1. Can convey the speaker's enthusiasm for the subject matter better than other methods.
2. Provides a role model of the scholar in action.
3. Can provide up-to-the-minute information, prior to publication.
4. Can provide special organization for the audience.
5. Can convey large amounts of factual material.
6. Can convey information to many people at once.
7. Provides maximum teacher control.
8. Provides little to no threat to students.
9. Emphasizes learning by listening, good for those students who learn best this way.
10. Offers human face-to-face interaction.

Weaknesses

1. Puts students into a passive state, which may hinder learning.
2. Lacks feedback both for the instructor and the student.
3. Requires an effective speaker to optimize method.
4. Not well suited to the higher taxonomy levels of application, analysis, and synthesis.
5. Not well suited to complex, detailed, or abstract material.
6. Assumes all students are learning at the same pace and level of understanding, which is seldom true.
7. Student attention wanes after 15-25 minutes.
8. Tends to be quickly forgotten.

Nevertheless, despite its weaknesses, the lecture survives as a primary method of instruction in colleges and universities. How can we create an effective lecture technique despite its inherent weaknesses?

The following are suggestions from the Ohio State Handbook for developing an effective lecture, combined with examples from cytotechnology. Consider the various segments of the lecture: the introduction, the body of the lecture and the conclusion.

Introduction

Capture the interest of the listener by making an expectation for the lecture, such as, "By the end of the hour, you should be able to identify the anatomic location of most cervical carcinomas." Another technique is to explain how the current topic relates to their professional career. "Today we will be talking about the CLIA '88 regulations, how they came about, and how they impact our current practice of cytotechnology."

Another suggestion is to relate current material to previous course material. Remember this also assists in helping the students create meaning and transfer learning. Example: "So far we have studied

the pre-malignant and malignant criteria for squamous cancer in the cervix. Today we will begin learning about glandular neoplasia in the gynecologic tract and later we will compare and contrast the morphologic features of the two."

Another suggestion is to tell the students how they are expected to use the material. Example: "Today we will be discussing problem solving techniques to use in trouble shooting problems in the lab. Later I will be giving you a series of scenarios for you to practice using these techniques."

Other suggestions include relating an actual case history or incident that is relevant, providing an advance organizer for the lecture, or giving the lecture an interesting title.

Body of the Lecture

Remember to emphasize key points and not to present minute detail to the point that students lose sight of the main objectives. Detail and nuances are better presented in the text. Cover the main 4-5 points that are made explicit. Several methods can be used to organize the body of the lecture.

Cause and effect: Discuss cervical infection with high risk HPV and how it appears to cause cervical neoplasia.

Time sequence: Discuss the steps in processing a cytology specimen in the proper time sequence.

Organizing idea: Compare and contrast various types of viral infection in the gynecologic tract.

Examples and illustrations repeatedly have been shown to increase understanding and retention of learning in the student. Appropriate case studies may also provide a "real life" example that helps students remember.

There is also an element of showmanship or acting which effective speakers practice. Varying the tone, speed, volume, etc. can emphasize what is important and what is less so. Be sure to observe the audience carefully for non-verbal cues as to confusion, lack of attention, etc. and be prepared to vary the pace. Stopping to ask pertinent questions, giving additional examples, or reemphasizing important points may be helpful. It is also helpful to provide the students with a visual or verbal reminder of the structure of the lecture. "There are five important concepts.... We have addressed the first two concepts, now we will be discussing the third, which is... And finally, the last concept, the most important of all, is...." This can be done verbally, as above, or by using the chalkboard, handouts, or other visual tools. This helps the student follow along. In any case, be sure the students come away with the major points.

Conclusion

To summarize the lecture, the main points can be restated by the class, either orally or in a brief writing assignment. Also, a new example can be given and discussed or the expectation of what was to have been gained by the lecture can be restated. For issues raised in the lecture that might be controversial, such as a discussion of ethics, the class could be divided into pairs or small groups and report on issues raised by the lecture.

Getting Feedback

One of the weaknesses of the lecture method is that it stifles feedback. This can be partially overcome by specifically working to obtain this information from the class. One can solicit questions or ask the students to summarize the main points or put the main concepts into their own words. Use the answers to correct misconceptions and refine understanding. Praise can be a very powerful motivational tool, so use it to comment on insightful answers, interesting points raised, etc. In addition to motivating the students, it has been shown to increase learning.

The Effective Use of Presentation Software

The ease of use of the various presentation software programs has been a boon to educators everywhere. A few suggestions for use are provided.

1. The **content** is more important than the technology. Be cautious of overly fancy or flashy presentation screens. Consider readability and create high contrast between the background and the text. Combinations such as yellow or white text on black or deep blue have been shown to be easier to read than a combination of mid-value colors, which do not contrast well. Ariel font (without the serif, the small ending mark present in Times New Roman) has been shown to be more legible as well. Strive for uniformity of color, font, and format so that the design is "transparent" and the content is the focus.

2. Limit the amount of information on each screen. Six words per line and no more than six lines per screen are considered appropriate. Better to use two slides than to cram too much information on one slide. Don't show a slide and say, "I know you can't see this but...".

3. Use laser pointers effectively to point out major areas of emphasis. Do not make repeated circles or other distracting patterns with the pointer. Have the slides move at an appropriate pace, neither too fast nor too slow. Research has found that students can usually understand a slide in 10-30 seconds. If you have finished with a slide, do not leave it on the screen while you discuss something else. You can put in another slide, or turn the projector off, or substitute a slide that is a picture, clip art, or other appropriate subject. Consider using animation to display complex and difficult to explain interactions or biologic process over time. An example might be an animation of the stages in the development of squamous metaplasia.

In summary, remember that there are inherent weaknesses in the use of the lecture format but that these can be at least partially overcome by good planning, the use of supplemental materials and assignments, and by practice to develop good speaking skills.

Advance Organizer: In contrast to the passive learning that usually occurs in lecture methods, active learning methods call upon the learners to create for themselves meaning in the content. This follows cognitive learning theory, which implies that learners must act upon the content in order to make it meaningful. Ways in which active learning methods can be used to supplement or replace lectures are discussed.

Active Learning: Tools for Cytology Educators

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One of the precepts of cognitive learning theory is that knowledge is not transferred intact from teacher to student, but that the student must act upon the content and construct their own knowledge framework. Students use previous learning, experience, and various activities to "make it their own."

One way that teachers can assist students in the task of making knowledge their own is to create opportunities in which the student must somehow manipulate the facts, concepts, and relationships to create a product (an oral report, a paper, a chart, or a discussion).

Some criteria of active learning include the following (Bonwell and Eison, 1994)[5]:

- Students are involved in more than listening
- Less emphasis is placed on transmitting information and more on developing students' skills
- Students are involved in higher-order thinking (analysis, synthesis, evaluation)
- Students are involved in activities (reading, discussion, writing)
- Greater emphasis is placed on students' exploration of their own attitudes and values

Remember, however, that the use of active learning in the classroom has some possible pitfalls. If these are anticipated, they can be addressed. The first is that one may encounter student resistance. It is easier, after all, to passively sit and take notes. The lecture method has been the most frequent teaching mode to which they have been exposed, especially in college. Secondly, there is often a certain degree of teacher resistance. We may feel we are "losing control" of the learning process since it is often less predictable than a standard lecture-based lesson plan. Also, it is easier to copy our lecture outlines, stand up, and launch into our favorite lecture. However, if one establishes expectations at the beginning of the course that student participation is required, then students are more inclined to participate. Utilize discussion and other active forms of learning early on in the course. Finally, make sure that the tasks are well thought out and relate directly to course objectives.

Discussions

Having students put concepts into their own words is an extremely effective way to encourage active learning. Additionally, it provides feedback to both the instructor and the student regarding their level of understanding. Misconceptions can be immediately addressed. Also, discussion has been shown to reinforce learning and memory.

Two main types of questions have been identified: targeted questions and open-ended questions.[6] They are best suited to differing types of content.

Targeted questions are those that have a specific, usually rather short answer. These are best suited when discussing factual detailed types of content. Probably these would be the most useful in cytology education.
Example: What are the main cytologic criteria for HPV infection?

[5] Bonwell, C., & Eison, J. (1991) *Active Learning: Creating excitement in the classroom.* ASHE-ERIC Higher Education Report No. 1 Washington, DC: George Washington University.
[6] Chism, N. et al. (1997) *Teaching at the Ohio State University*, 4th ed., p. 60.

Open-ended questions, on the other hand, are those that may have divergent answers. For example, when discussing ethics and the health care system one might ask "What are some ethical dilemmas that might arise in the laboratory?" Encouraging expansion of the responses by asking for additional thoughts from others and allow ample time for responses.

Several verbal and non-verbal cues can assist in encouraging participation:

1. That's a good idea. What does anyone else think about that?

2. So you were saying that you think CLIA '88 regulations are not strict enough? Why do you think that?

3. What are other ways we could look at this same problem?

4. Smiling and nodding while listening to a student encourages further responses.

5. Sitting down with the class in a circle also encourages interaction among the students.

Be sure to give adequate wait time (at least 10 seconds) before rephrasing the questions. Research has shown that instructors usually do not allow enough time for students to answer.

One can place the students in pairs with a specific topic to discuss and a time limit. Then the answers are shared with the group as a whole. Short writing tasks, such as giving them five minutes to write their answer to the question on the board, can also be used to begin a lecture or to summarize thoughts at the end.

Encourage participation and respectful behavior by discussing ground rules. These should include an emphasis on letting everyone have their say and being good listeners. Emphasize that everyone's comments can be valuable even if they are out of the mainstream.

Summarize at the end of the discussion so that the students can appreciate the main points covered. Additionally, points not raised can be covered and feedback can be given as to the quality of the discussion.

A critically important class discussion period in cytotechnology takes place around the multi-headed microscope. This format can be used in several ways:

1. Illustrate with actual glass slides the entities just covered in lecture. Usually the instructor will point out helpful clues *("Note the broken polys in the background of this candida case.")*. One can also note pitfalls of diagnosis *("One must be especially careful to pick up on these isolated, single, small high-grade cells.")*. Difficult differentials can also be discussed *("Compare how the cells of this small cell carcinoma of the cervix may somewhat resemble the endometrial cells we just looked at. However, note how the cytoplasm differs.").*
2. Review with the students, cases from the teaching file about which they have questions.
3. Review practice glass slide tests. It is important to go over even the slides everyone correctly answered (Was it just a lucky guess?) as the students can be praised for their correct answers and one can inquire, *" Why did you think this was HGSIL? Why didn't you call it LGSIL?"* Insight into their diagnostic criteria and process can be invaluable in strengthening these skills. They will quickly learn how to verbalize and quantify their diagnostic answers if responses such as "*Because it looked bad*." are not accepted. Require that they expand their answer by asking, "*What criteria made you come to that conclusion?"*
4. Always be supportive, praise correct answers, and remember that even incorrect answers may show logical thought patterns and point up a discrimination problem that can be addressed. *"I see where you are coming from. You did notice there are an unusually large number of lymphs here, some of which are immature. However, notice the range of maturity present and the other types of inflammatory cells, such as plasma cells and histiocytes. So lymphoma must be excluded and this is most consistent with chronic follicular cervicitis."*

5. Finally, reviewing actual glass slide tests can be an opportunity to eliminate a misconception or fine-tune a difficult differential problem. Students may learn more from making a mistake than from getting the question correct. A word of caution: depending on their temperament, some students may find this common sharing and discussion of errors very stressful. Be sensitive to their feelings and if one student utterly fails a glass slide test when the others have done well, some one-on-one help may be a better use of class time. This may help the student to more openly discuss their errors.

Writing assignments

Writing is also an excellent method of engaging the students in their own learning. These can be formal papers at the end of a term, interesting case studies, or brief summaries (½ page) at the end of class to help the student summarize main points. Brainstorming tasks (*Make a list of criteria to use when evaluating viral disease.)* can also be useful in evaluating student learning. These can be compared in class and discussed.

Be sure to provide clear criteria for evaluation of writing assignments and for formal papers, good examples from previous classes to give as models to the students.

Problem Solving

This is an active learning tool that is particularly useful for cytotechnology educators, since our students often must use these skills in the workplace. Discussions of problem-solving strategies such as defining the problem, gathering data, generating hypotheses, testing them, and checking for results may help students who have little experience in this area. It is particularly important for students to avoid the trap of immediately jumping to conclusions regarding, for example, a poorly stained slide, without considering all the possible causes. Giving a demonstration of how to go about tackling such a problem and then immediately following that with some problem solving exercises can be very effective in teaching these skills.

Case Studies

As previously mentioned in the writing section, case studies formally written up can be very effective learning tools. Also, students can participate and eventually select cases for glass slide case conferences in which the participants are given only the slides and the patient history. Then each participant must give his/her diagnosis. It is especially instructive if the pathologists can participate in this exercise so the students can model the diagnostic thinking process used.

Finally, other kinds of assignments such as making a diagnostic flowchart, creating a sketch, creating a table comparing two entities, and so on are all ways to actively involve the learner.

Computer-Assisted Instruction

Active learning is inherent in well-designed and implemented computer-assisted instruction (CAI). A myriad of studies have been conducted to evaluate the effectiveness of CAI. A comprehensive review of more than 50 studies conducted by Cotton, K (1991)[7] at the NW Regional Educational Laboratory showed that, though the results of studies regarding effectiveness of use of CAI alone as compared with traditional instruction alone are inconclusive, CAI used as a supplement to traditional, teacher-directed instruction produces higher achievement effects as compared with traditional instruction alone. In addition, the review demonstrated that CAI enhances learning rate and increases retention of content.

There are numerous programs available in Cytology that simulate books using the computer and these are undoubtedly a valuable resource. However, they are not technically computer-assisted instruction. An effective CAI tool, whether used as a stand-alone or as an adjunct to traditional teaching methods, provides not only written and/or visual information, or instruction, via a computer, it also

[7] The Northwest Regional Educational Laboratory, School Improvement Research Series: Series V (1991-1992). Close up #10. Cotton, K. Computer-Assisted Instruction. Available at: http://www.nwrel.org/scpd/sirs/5/cu10.html. Accessed October 22, 2004.

provides an opportunity for interactive learning as the learner progresses through the instructional exercise. CAI can be used to enhance a student's knowledge while at the same time provide an opportunity to challenge, quiz and reinforce students.

CAI is learner controlled and therefore provides for individualized instruction. Students can proceed at their own pace, whether slow or fast, digesting and practicing new knowledge and/or skills at a rate that is most comfortable for them. CAI also affords a measure of privacy so that students need not be embarrassed at requiring a slower pace than their classmates or at making mistakes. Additionally, CAI can ensure comprehension of new material by providing immediate, objective feedback and reinforcement before proceeding onto new information. Because of this interactive and participatory nature of CAI, it increases chances of retention.

Like traditional teaching, CAI can employ a variety of instructional strategies to accomplish its goals and objectives:

- Drill-and-practice: After presenting a fact, term or concept, the learner identifies and chooses the correct answer based on the information presented. The learner then can receive feedback for correct and incorrect responses.
- Tutorial: Throughout presentation of facts and/or concepts, the learner interacts with the instruction by answering questions, thus measuring the learner's understanding. Based on the learner's response to the questions, the learner can further progress with the instruction or can have an opportunity to review again areas that presented difficulty.
- Gaming: A goal-oriented activity is used employing a set of rules that specify how the goal can be attained.
- Problem solving: The learner is required to use previously acquired knowledge and/or skills to solve a problem. Focus is on the process of steps used to solve the problem.
- Model building: The learner constructs and tests a model.
- Testing: The learner is evaluated on the acquisition of knowledge, skills or attitudes.

Unfortunately, such CAI for cytotechnology education is limited, if available at all, on the market. Extensive programming skills and background are not essential for the software required to develop CAI, but the software can be extremely expensive, though significant educational discounts are often available with some research. However, if funds and time are available, developing CAI specific to cytotechnology can provide an effective mechanism to promote active learning.

The process of developing a CAI can be described in five steps:

- **Selecting and Writing the Content:** The same principles that apply to traditional teaching methods also must be applied to CAI tool. Content must be carefully planned and written, including goals, objectives, text, graphics and illustrations, charts, examples, practice exercises, pre-test and post-test. A pre-test can help the student to establish the knowledge base that will be required to proceed further and assess his/her need to review previously learned material. Immediate feedback to the test is essential.

  In addition to the actual text, the CAI should utilize supporting illustrations, examples, photographs, etc. Practice exercises and questions should be developed and incorporated throughout the text to ensure comprehension of new material before proceeding further, provide repetition of content and provide mini-self assessments for the student.

  Lastly, the post-test helps the student to determine if he/she has successfully achieved the goals and objectives, and if not, on what areas he/she needs to focus.

- **Choosing appropriate technology:** Educational goals as well as cost limitation must be taken into account. At minimum, hardware (Macintosh or Windows-based) and authoring

software is required. Additional equipment that could be useful includes a scanner, digital microscope camera, photo-enhancing software and CD record able drives.

- **Designing the CAI:** As in selecting and writing the content, the design must reflect sound educational principles in order to be effective. Considerations in designing the CAI include selection of methods to present content and supporting graphics and options that are necessary for the student to maneuver throughout the CAI. At minimum, an effective CAI should include:
  - Clear learning goals and objectives – these should be presented early in the program
  - Interactive participation and effective reinforcement – this could be achieved through activities such as drill-and-practice exercises with immediate feedback or diagrams that require clicking on various parts of it to reveal more information.
  - Immediate feedback – this is critical whether responses are correct or incorrect. Positive reinforcement is as essential as informing the student his/her response is incorrect
  - Repetition of material – repetition in small batches is important, particularly for items that were missed in exercises or for complex concepts
  - Ample user accommodation and/or learner control – the CAI must be user friendly with clear instructions. The learner should have opportunities to select from menu options that allow for manipulation through the program at his/her own speed.
  - Consideration of concepts important to presentation of multimedia – information should be presented in the simplest manner possible and grouped together into like patterns or grouped in usable ways to assist the student in retention of content; important concepts should be emphasized with labels or visual clues; diagrams and graphics should only be used if they support the content and should be referenced and explained; reference points, comparisons and contrasts, examples should be provided for difficult concepts; appropriate colors, fonts, size should be used.

- **Programming the CAI:** Utilizing the authoring software, one can often take advantage of various built in instructional tools.

- **Implementing and Evaluating the CAI:** Prior to incorporation into the curriculum, it is helpful to have it evaluated by other program faculty as well as students. The evaluation should focus on the design of CAI as well as design and the student's attitude towards the CAI. Once incorporated, an evaluation at the end of the exercise helps to ensure continual improvement and development of the CAI.

In conclusion, CAI has been shown to have numerous benefits. A carefully designed computer-assisted instruction that incorporates sound principles of education can be an invaluable tool for active learning in cytotechnology programs when used as a supplement to traditional teaching methods.

Thus, utilizing active learning methods, whether in addition to lectures or sometimes alone, are very effective tools in helping students construct their mental framework of new knowledge. Tools such as discussion, multi-head microscope sessions, writing assignments, problem solving scenarios, case conferences, charts, sketches, and other projects can be used to great advantage. Additionally, authoring software can be utilized to write computer-assisted instruction that can also be an interactive, effective learning tool.

Advance Organizer: It is challenging to teach students how to approach the reading of scientific journal articles. There is a tendency of the student to assume that if the article has been published, the conclusions reached must necessarily be correct. Additionally, the student often misses the underlying assumptions that the researchers have utilized, even when these assumptions have led to an incorrect conclusion. Also, there is the need to illustrate the difference between what was measured in the experiment and the conclusions reached. In other words, how does one analyze the adequacy of the number of participants in the experiment? Or the adequacy of the research design? Or the adequacy of the response to interobserver variability? The Vee diagram has been used to help students analyze research articles and their conclusions. It helps the students get beyond the "bare bones" of the article, into a more thoughtful analysis of the quality of the research.

The Vee Diagram: A Tool for Teaching Critical Reading Skills

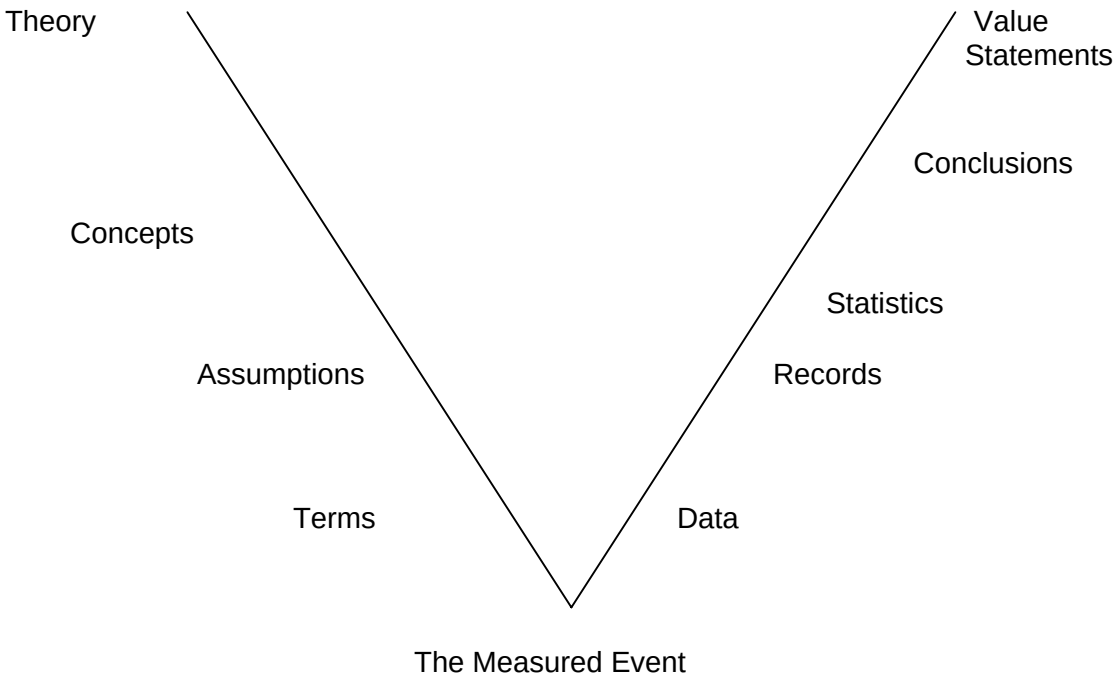
Marilee Means, Ph.D., SCT(ASCP)

Gaining an appreciation for the use of the scientific method in cytology research is one of the competencies cytology programs have met through a variety of methods. Often, the study of several research articles is undertaken in order to provide a basis for discussion and for the teaching of critical reading and analysis skills. Having participated in the reading and discussion of journal articles in advanced cellular biology while in graduate school, I knew it was often difficult for a novice to even understand the point of the articles, let alone try to critically evaluate the results. Thus, I adapted a tool used by educators in high school science courses for laboratory experiments, the Vee diagram.

The Vee diagram is a symbolic analysis tool that students can use to describe both underlying concepts and assumptions used in the article, as well as the validity of the conclusions reached after the completion of the experiment. Thus, it forces the students to discover the "unspoken" portions of the research and consider these as well as the actual data recovered in the experiment. I have found that it is also often difficult for the students to analyze the conclusions reached in the experiment. This tool can assist them with that task.

The Vee diagram is a large open "V" shape that has labels along each axis and the "measured event," the actual experiment, summarized at the point of the "V". (See **Figure 1**)

Figure 1: A Vee Diagram



For example, let us look at how such a diagram would be completed if the students were assigned to read a modern day repeat of Pavlov's famous experiment in which dogs were conditioned to salivate at the ringing of a bell.

The abstract of such an article might read as follows: After having conditioned 15 dogs to associate the ringing of a bell with the presentation of food for a period of 4 weeks, these dogs were observed for the presence or absence of salivation when the stimuli of the bell only was presented. This was repeated again at 2 week and 4 week intervals after the end of the conditioning. A control group of 15 dogs that had not been so conditioned was also observed for salivation with the bell stimuli at 0 weeks, 2 weeks, and 4 week intervals.

The students are presented with the diagram and the sections of the diagram are discussed. Beginning with the "Theory" category, it is pointed out that although usually the underlying theories are not specifically discussed in the article, the researcher often relies upon the work of others in order to provide a conceptual framework for his unique work. In our current example, the theories of "Behaviorist Learning" would be an obvious choice.

Next, the category of "Concepts" is given. This is usually more specific than the more general "Theory" category. "Conditioning" and "Stimulus/Response" would be two more specific categories of behaviorist learning theory that would apply to this experiment.

Next, the "Assumptions" category allows the student to examine the often, unstated assumptions that the researcher may have made when setting up the experiment. An example in this case might be that "salivation is linked to the presentation of food." This was assumed but not directly tested in the experiment. If one or more of these assumptions is not correct, it may lead to an incorrect conclusion on the part of the researcher.

Finally, I usually explain the "Terms" category as being similar to a list of vocabulary words needed to understand the article. The definition of these terms can be a source of error for the researcher, especially if the terms used are not adequately defined. In our example, "Salivation" was a marker for the presence of conditioning. How did the researcher define the presence of salivation?

The "Measured Event" can usually be adequately explained to the students by asking them exactly what did the researchers measure? They need to understand that the researchers were measuring results in a specific time and place with specific participants and not something abstract such as "the effects of conditioning." Thus, in our example, the response could be something such as:

15 Conditioned dogs presence of salivation 0, 2, and 4 weeks
15 Unconditioned dogs presence of salivation 0, 2, and 4 weeks

Note that in the "Measured Event," the results are not discussed. Also, point out to the students that usually this information is present in the "Materials and Methods" portion of the research article. Also, this "bare bones" statement of what was measured is the most concrete portion of the article, and the least susceptible to misinterpretation and researcher error. No matter how various scientists might interpret the resulting data, usually there is no controversy about exactly what was measured. Usually, students can identify this category accurately and quickly, once they learn what to look for.

Next, as we proceed up the left hand side of the "Vee," note to the students that step-by-step we are getting further away from the measured event, both in degree of abstractness and quite literally on the diagram. Also, point out that this right hand side of the Vee is very prone to research error, especially as they proceed up to the final categories of conclusions and value statements. Here they must carefully examine the logic, the research design, the quality of the data, the use of statistics, etc. to see if they would "bet the farm" on the quality of the conclusions reached or not.

The first category to the right of the measured event is "Data." It is often difficult for students to realize that even this first summary of the results of the experiment may contain the seeds of research error. To them, facts are facts, no matter how they were obtained. In our example, "Data" might contain something like the following:

14/15 conditioned dogs salivated at 0 weeks, 10/15 at 2 weeks, 3/15 at 4 weeks
0/15 unconditioned dogs salivated at 0, 2 or 4 weeks

The "Records" section may also elucidate for the students common research problems they usually do not detect such as interobserver variability. If the research article does not comment on how the records were made this should be noted by the student and kept in mind when evaluating the article's quality. In our dog experiment, for example: The presence or absence of salivation was determined by two separate researchers using a yes/no checkmark. Agreement between both researchers was needed for the data to be compiled.

The "Statistics" section is where the summary data (such as mean, standard deviation, p value) and the analytical data (such as Chi Square, ANOVA, discriminant analysis) can be detailed. Here again, misuse of statistical analysis may need to be pointed out to the students. Would you want to "bet the farm" on a statistical analysis that says that out of 3 patients, 1 (33%) of them were positive for HPV infection? In our dog example, this section might say something like:
89% of the conditioned dogs salivated at 0 weeks
66% at 2 weeks
33% at 4 weeks
0% of the control group salivated at any of the intervals

When compared to the control group, the p values of the results were $< .00001$, $< .0001$, and $<.01$ respectively.

The "Conclusions" section can usually be identified by the students. One can point out that this information is usually contained in the "Discussion" section of the research article. However, again the students may have difficulty with critically analyzing the adequacy of these conclusions, given the supporting data. In our example, this section may say:
The ringing of the bell, when combined with the presentation of food, apparently was able to trigger a response (salivation) unrelated to the bell itself. This happened in most dogs (89%) after 4 weeks of conditioning, but after the withdrawal of the stimuli (food), the response gradually extinguished over time.

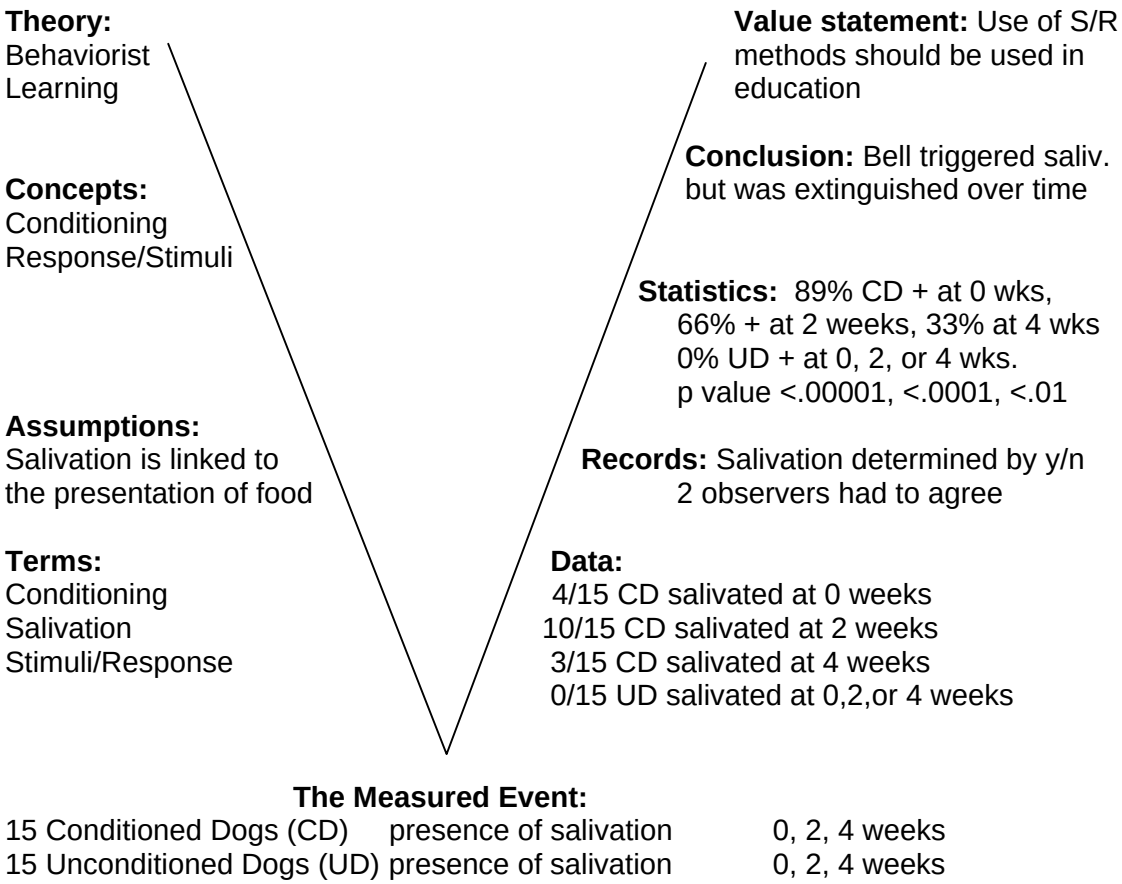
Finally, the "Value Statement" is the section of the research article in which the researcher ascribes a certain importance to the strength of his conclusions. This statement is usually preceded by a stated or implied "should" in the sentence. For example, the researcher may conclude that the research is merely the initial investigation into the matter at hand and is preliminary. Therefore, he or she may suggest that, "More research into the relationship between HPV and cervical neoplasia should be conducted." Or the researcher may suggest that clinicians apply the research findings to the treatment of their patients. "All patients with a positive HPV result should have a colposcopically directed biopsy of the cervix." Note to the students that they need to evaluate the researcher's value statement critically in light of the supporting evidence given. It is a serious and significant matter to suggest changing the status quo of medical practice based on one piece of research. Do the findings support such a change? Is this conclusion based on too few patients? Too short a time period of follow up? A study that has many errors of design?

In the dog conditioning experiment, the value statement could read as follows:
The use of stimulus/response methods in education should be employed to reward desired behavior and to reduce or eliminate undesired behavior.

As one can see, this is a rather far cry from ringing bells in front of hungry dogs. As the most abstract and far-reaching portion of the research article, it is the furthest from the "measured event". The student is advised to make certain that their evaluation of this statement takes into consideration all the information on the right hand side of the diagram. Again, often the students must be directed into this arena of analysis. However, if they have completed a Vee diagram prior to classroom discussion, they are much better equipped to pick up on the possible areas of critical evaluation than if they have merely been assigned to read the article. See **Figure 2** for an example of a completed Vee diagram.

Thus, the Vee diagram is an active learning tool that educators can use in order to assist their students in becoming critical readers of research articles. It involves the students in at least a preliminary analysis of the quality of the article and can provide a much stronger basis for classroom discussion than just a cursory reading of the article. It also graphically illustrates how research is based upon prior theories and other research, how the measured event itself is the crux of the article, and how many possible sources of research error may infiltrate as one collects the data, analyzes it, and reaches conclusions and value statements.

Figure 2: Example of completed Vee diagram for Pavlov's experiment



Advance Organizer: Incorporating new technologies into the cytotechnology curriculum is a challenge for many programs. While most of the essays in this handbook focus on methods to teach cytotechnology, these next two articles focus on this new content area. These articles appeared previously in *The ASC Bulletin* and are reprinted here by the kind permission of the author.

Embracing a Brave New World: Molecular Diagnostics for Cytotechnologists Part I

E. Blair Holladay, Ph.D., CT(ASCP)

Introduction

These days, molecules and diagnostic pathology are getting linked, often right under your microscope! The molecules that comprise DNA are central to understanding genetics, heredity, and disease. The advent of molecular diagnostics in the early 1980's allowed for a veritable explosion in diagnostic science, namely due to our ability to clone unlimited fragments of genes via a process that is referred to as polymerase chain reaction. From our incipient understanding of this pivotal science have emerged myriad diagnostic applications that have dotted the landscape of modern diagnostic medicine. With unparalleled sensitivity and specificity, the utility of these tests is simple - earlier and more specific diagnostic information that can be used by clinicians to better the management of our patients. Ironically, the beauty of sensitivity and specificity that can lead to an earlier diagnosis may also be molecular science's greatest limitation. Medicine must, in fact, have pragmatic utility. Clinicians cannot always confirm diseases that are not clinically apparent, and often-sensitive molecular tests encourage unnecessary therapeutic interventions and expensive consequences for our patients, as well for our providers. Nevertheless, this delicate balance of sensitivity and positive predictive value will likely be medicine's savior and nemesis as a plethora of molecular diagnoses emerge in our profession. And emerge they will, with the force of lions. Our job must be to take a careful scientific approach such that each of these newly developed scientific tests are carefully validated and scrutinized as compared with the current standard of care.

Why should Cytotechnologists be performing molecular diagnostics?

The answer to that question is simple - *because we can and because these new techniques are intimately related to a basic tenet of cytology, the detection and prevention of disease*.

Most of us did not enter cytology because we were interested in becoming clinical laboratory scientists. Cytologists have significant expertise in the area of cancer diagnostics, and to a smaller extent, infectious disease and these both are relevant areas of molecular diagnostics. Virtually every tissue of the body with known pre-malignant and malignant diagnostic cellular processes (gathered by exfoliative means or fine needle aspiration biopsy) may be initially detected by the cytotechnologist. From cervical cancer to soft tissue sarcomas, from lung, GI, and urinary tumors to melanomas and central nervous system tumors, there is a gamut of expertise practiced daily, and our knowledge base continues to grow. The evolution of cytopathology has grown from one that was captured yesteryear in simple monographs to today's tomes of monolithic proportions.

The current pervasive role of molecular diagnostics as related to cytology is its use as "reflex" testing for equivocal interpretations, and as testing to provide information about crucial molecular inferences of malignancies, both of which allow the clinician to better manage their patients. Obviously, this improved diagnostic conduit allows treatment to be individually tailored. These molecular profiles take the science of cytopathology one step further and ultimately improve detection, prognosis, and allow for the customization of specific therapeutic regimes.

When will this occur?

This nexus between cytology and molecular diagnostics has already begun in laboratories across our country and throughout the world. Cytotechnologists already provide the initial interpretation, and because many technologists working in the laboratory today have biochemistry experience or background, performing molecular testing seems a natural liaison for these professionals. From recent ASC surveys (conducted by the CAC), data reveal that cytotechnologists are qualified under the law to

conduct many molecular diagnostic assays due to their classification by the Centers for Medicare and Medicaid (CMS) as professionals performing high complexity testing. States with added licensure laws may also govern whether cytotechnologists are allowed to practice in the area of molecular testing. The surveys reveal that most states with licensure have no regulations that prohibit cytotechnologists from performing molecular testing, with the notable exception of California. The states of Tennessee and Florida are evaluating the legality of this issue at the present time.

Recently, the American Society of Clinical Pathologists (ASCP) developed a new certification category, the Technologist in Molecular Pathology, or MP(ASCP). Cytotechnologists currently practicing, or those graduating from an accredited cytotechnology (CT) school (mandated by CLIA to possess a baccalaureate degree or greater), are eligible to sit for the examination without experience. Many CT programs are addressing this issue by integrating molecular techniques and experiences as part of the educational program for their students so that the students feel prepared to sit for dual registry exams upon graduation. Information pertaining to the MP(ASCP) exam, and a breakdown of content specific areas of the test, can be found by accessing the ASCP website. [1,2] Several preparatory texts are also available and a free "Molecular Technology" website and CD ROM (developed by Roche Diagnostics) are also helpful preparatory tools. [3,4]

Why Should You be Interested in Molecular Diagnostics?

To date, over 5000 diseases have known or direct genetic relationships. Molecular tests to detect genetic variations have high sensitivity, can be standardized, and have added diagnostic utility that complements diagnostic cytopathology. Compared to many laboratory assays (such as immunohistochemistry and special stains), molecular tests are generally rapid and often semi-automated. It is important to remember, however, that medicine is founded on a pragmatic approach to disease detection, which includes concern for the single largest controversial issue surrounding the popularity and utility of these tests, that is to say – their expense that may limit their routine use. Fortunately, molecular testing prices are falling. Because many of these tests require diagnostic interpretation (for instance, in situ hybridization), there seems to be a natural reason to marry the tests with our cytopathologic analyses, and thereby serve to keep these assays in the anatomic laboratory - where the profit from testing can be shared. Why should the profit from these assays be credited solely to the clinical side of laboratory medicine if cytologic interpretation is a function of the assay? These are hot-button issues yet to be decided that will have great impact on laboratory structure and personnel function.

Molecular Techniques in Diagnostic Pathology

It is not the intention of this article to describe each of the techniques utilized in the diagnostic laboratory, but rather, only those tests that are germane to areas of diagnostic medicine most commonly practiced by cytotechnologists/cytologists. Clearly, many standardized assays utilized in today's laboratory may be better suited for medical laboratory technicians or clinical laboratory scientists (medical technologists) such as the array of infectious disease assays (HIV, HBV, HCV, etc). However, what tools and technology does the cytology laboratory currently utilize? What specimens do you have access to for reflex testing, as well as other adjunct molecular assays?

Part I of this article focuses on three major molecular technologies that are converging into the area of diagnostic cytology: Hybrid Capture, In situ Hybridization, and the Polymerase Chain Reaction (PCR). By utilizing these three main techniques, the cytologist can gain a foothold into many assays that are both complementary to cytology and financially lucrative for the laboratory.

A. Hybrid Capture (HC)

Currently, the latest version of this technology (HC II) developed by Digene Corporation (Gaithersburg, MD) uses a nucleic acid (signal amplification) hybridization on a microplate assay. Using chemiluminescence, a positive event (i.e. the target DNA) is detected and quantified. Up to 96 specimens (including multiple controls) can be run in tandem. This is a manual assay that requires digital pippeting followed by semi-automated analysis. The assay is not morphology-based, but rather provides a computerized print out of the sample test results. The basic steps include specimen denaturation, nucleic acid hybridization with RNA probe, the capture of hybrids onto a solid phase, and the conjugation of myriad enzymes to the "captured" hybrids. The hybrids react with a substrate to produce an amplified

chemiluminescent signal for each patient specimen. Hybrid capture testing can occur direct from the vial (Digene specimen transport medium) or can be run using residual liquid-based cytology samples (FDA approved for ThinPrep Pap test only). The throughput for these 96 specimens is around four-five hours per run. More recently, a high throughput system for hybrid capture, Rapid Capture, is available for large batch processing for high volume laboratories. This system can run 300 specimens per day using an automated technology (only FDA approved for CT/GC to date).

B. In situ Hybridization

In situ hybridization (ISH) uses a morphology-based microscopic interpretation as its final diagnostic platform. Although similar to immunohistochemistry (which uses a protein, i.e., antibody to attached to another protein, i.e., antigen), ISH uses a nucleic acid probe to hybridize to a complementary nucleic acid target. Specifically, a single stranded RNA or DNA probe, which in turn, detects an mRNA target molecule either in a tissue section, or liquid-based cytology sample. The target detection via ISH can occur either with bright field microscopy (chromogenic markers within positive nuclei) or with fluorescent-labeled probes (FISH). Furthermore, FISH can detect chromosomal copy number as well as gene expression. A semi-automated technology developed by Ventana Medical Systems, Inc. (Tuscan, AZ), referred to as the Benchmark, uses the eight steps necessary to accomplish ISH (baking tissue to slide, deparaffinization (if tissue), specimen pretreatment using heat to unmask the target, denaturation of nucleic acids with high heat, hybridization of probe to target nuclei acid by reducing the temperature, stringency washing to remove excess probe, molecule linking using chromogen or fluorescent probe linked to a primary antibody, linking a biotinylated antibody and eventually alkaline phosphatase conjugated avidin to allow for visual detection, and lastly counterstaining for background evaluation by the evaluator). The throughput for the Ventana Benchmark is roughly 20 specimens per four-five hours. Smaller batches of specimens (for medium to smaller laboratories) for reflex testing is conservative, using only the amount of reagent required for the total number of specimens loaded for analysis (two of more), as opposed to the batching required with microplate technology-based systems.

The FDA currently relegates ISH procedures as analyte specific reagents (ASR), indicating that any laboratory utilizing this technology must perform valid in-house testing and compare the resulting data against known in vitro diagnostic tests (if available) or know gold standards (based on sensitivity and specificity values) for determination of validity. Laboratories are regulated by CLIA guidelines (not the FDA), and as such, may bill or request third party reimbursement for ASR technologies.

C. Polymerase Chain Reaction (PCR)

This revolutionary science has allowed scientists to amplify or clone a minute amount of nucleic acid (>10 copies of DNA) in a qualitative and quantitative fashion such that sub-clinical or early infections and pre-cancerous or early neoplastic events can be readily detected after visualization in gelatin-based substance. The process mimics that which occurs in vivo during DNA synthesis; thus, the role of PCR in the molecular evolution has been unparalleled. The process uses a series of temperature variations to allow for the separation of DNA molecules into single strands and hybridization against short single strands of complementary (‘3 and ‘5) RNA primers (oligonucleotides usually 20-30 nucleotides in length) bracketing the targeted amplification site. It is at these primer sites where DNA replication begins. Using a large quantity of available primer sequences within the reaction, in addition to a key enzyme (Taq polymerase), the reaction is catalyzed in the presence of an available pool of the four essential nucleotide triphosphate bases (Adenine, Thymine, Guanine, Cytosine) and the co-factor ($MgCl_2$), which helps amplification efficiency. Efficiency occurs best under controlled temperature variations using an automated thermal cycler. The cycler heats the target DNA to 95 degrees centigrade separating the dsDNA (denaturation), the temperature is dropped to 55 degrees centigrade to allow for the complementary primers to anneal by way of hydrogen bonding (hybridization), and the nucleic acid (in the presence of the essential nucleoside triphosphates) is extended with the polymerase (extension). The tri-fold cycle is repeated over and over to allow for exponential amplification of the targeted gene product, such that after 30 cycles, amplification produces over one billion copies of the target genetic sequence. Finally, the genetic copies can be visualized and analyzed after separation into smaller fragments using gel electrophoresis. Within the thermal cycler, 96 micro tubes or patient samples can be simultaneously amplified. This platform also has increased flexibility for multiple testing (multiplexing) of differing reaction types. In 1991, Roche, Inc. (Indianapolis, IN) purchased the patient for PCR testing--thus began the

commercialization of the PCR process in the clinical laboratory. Today, and in about five hours, the potential to screen for a host of clinical diseases has evolved using instruments such as Cobas Amplicor and the Light Cycler. The utility of this process plays a formidable role in targeted areas of cancer diagnostics.

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Specific Applications of Molecular Diagnostics for Cytopathology
Part II

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There are numerous molecular applications used in the clinical laboratories. "Part I, Embracing a Brave New World: Molecular Diagnostics for Cytotechnologists," focuses primarily on those categories, as well as those that are relevant to cytopathology. In Part II, the major areas for discussion are infectious disease markers and oncology markers.

A. Infectious Disease Markers

1. **Human Papillomavirus (HPV):** The 2001 Consensus guidelines for the management of women with cervical cytology abnormalities recommends reflex testing for high risk HPV with liquid-based Paps (LBP) as part of the management algorithm for patients with the equivocal cytologic interpretation of ASC-US, in part due to the relationship of high risk subtypes in the development of cervical cancer.[1] Furthermore, the American College of Obstetrics and Gynecologists strongly prefer ASC-US triage in the management of these cytologic interpretations and suggest laboratories establish automatic referral for high-risk HPV DNA testing for all Pap tests interpreted as ASC-US. Each of the technologies listed above, Hybrid Capture II, Ventana's Inform HPV and PCR can be utilized for determining high-risk HPV DNA. HCII and ISH assays detect the 13 most common high-risk HPV types and can be reflexed from the LBP or collected into a cervical sampler media (Digene) for direct evaluation. More recently, the FDA has approved HCII testing as a primary adjunctive screening assay with Pap test (either liquid or conventional) for women aged 30 and older. To date, the only in vitro diagnostic test approved by the FDA is Digene's HCII. Inform HPV is under consideration as an analyte specific reagent (ASR) and PCR testing is still considered for research purposes only (RO) or a "home brew" assay. A PCR-based assay for use as an ASR is under development by Roche, Inc.

2. **Chlamydia trachomatis (CT) and Neisseria Gonorrhea (CT/GC):** CT and GC are the most common bacterial infections of the lower genital tract (700,000 cases per year) and most often occur in asymptomatic females. These sexually transmitted infections are linked to pelvic inflammatory disease (PID), ectopic pregnancy and infertility. Although in the past testing for CT/GC has often occurred independent of the LBP testing, recently the verification of both organisms have been approved by the FDA with LBP's using Digene HCII testing; therefore, a comprehensive screening for both HPV and CT/GC from a single vial and a single office visit by the patient can be performed. CT/GC analysis has also been approved by the FDA for testing with Digene's Rapid Capture semi-automated system, allowing for high throughput testing. Esoterics, Inc. has a PCR-based assay for use with LBP tests in females and urethral smears in males. Lastly, Roche, Inc., Abbott, Inc (Abbott Park, Il) and Bectin-Dickinson (Franklin Lakes, NJ) all have molecular assays (Amplicor, GeneProbe and ProbeTec) for the detection of CT/GC with the use of endocervical or urethral swabs as well as urine samples. These assays are not generally reflexed from LBP specimens.

3. **Cytomegalovirus (CMV):** Active CMV infection in the fetus or newborn may cause nervous system disorder and hearing loss or failure to thrive; and may prove life-threatening in immunocompromised persons (solid organ or bone marrow transplant patients). Early and accurate detection of this infection can help clinicians improve patient management with anti-viral therapies. The detection of CMV is commercially available using HCII (the only FDA approved test) or Ventana Inform CMV. HCII diagnosis is made from peripheral white blood cells while Inform CMV is detected in tissue sections from any organ system (as compared to immunohistochemical assays).

B. Oncology Markers

Oncology markers are used to assess the genetic mutations for each individual patient's tumor (a.k.a. tumor profiling), thus helping guide the clinicians in selecting the most appropriate therapeutic regimen (for instance, N-myc amplification in neuroblastoma as an indicator of cisplatin resistance). The

drive for development of molecular pharmacogenetics is opening new doors to the laboratory practitioner with the resulting prognostic indicators being used for the assessment of individual tumors—again guiding clinicians to select the most appropriate therapeutic modality.

1. **Breast Cancer (Her2/neu and Topoisomerase II):** Twenty five to 47% of breast cancer patients overexpress Her2/Neu gene on chromosome 17 (17q11.2-q12), which is generally associated with ER/PR negativity and a poor prognosis. Determining which patients overexpress this gene can help triage patients and determine those that may benefit from Herceptin (trastuzumab) therapy. Because immunohistochemistry (IHC) or protein overexpression for Her2/neu often is difficult to discern (due to weak positive signals or background staining), Several studies have shown a large percentage of tumors considered positive by IHC (>=2) for Her2/neu by IHC showed no gene amplification (presence of detectable mRNA); therefore, ICH was falsely positive.[2,3,4] FISH testing may have a sensitivity and specificity of 96-100% for assessing over expression of the Her2/neu gene; therefore, the molecular analysis of this gene using in situ hybridization (FISH) may increase the sensitivity of the test thereby enhancing the opportunity for therapeutic triage. Vysis, Inc. (Abbott Park, IL) PathVision® assay (a dual colormetric marker) and Ventana's Inform assay (single colormetric marker) use FISH technology, while the Light Cycler (Roche, Inc.) uses PCR for analysis of Her2/neu and topoisomerase II gene, a gene located near the Her2/neu gene that if amplified would guide clinical intervention with topoII inhibitor drugs (epi/doxorubicin).[5] Chromogenic ISH assays for Her2/neu (for use with bright field microscopy) are currently under development and offer promising options to fluorescent microscopic interpretation.

2. **Bladder Cancer:** Bladder cancer accounts for up to 55,000 cases of cancer per year in the United States alone, with a death rate similar to that of cervical cancer (12,500). Although the sensitivity of cytology is good for establishing the diagnosis of high-grade urothelial tumors, low-grade tumors are difficult and often impossible to distinguish from benign urothelial cells. Furthermore, most bladder cancer recurs, and early recurrence is often difficult to detect cytologically with cystoscopic specimens. A number of adjunctive immunological assays are commercially available for determining recurrence (BTA-Stat, ImmunoCyt); however, these tests have not shown utility for confirming the primary diagnosis of low-grade urothelial neoplasms. Molecular genetic methods are often research-based (microsatellite analysis, telomerase) although commercially produced cytogenetic methods are available. These include FISH-based assays, such as the Vysis Urovision test- a multi-color test that detects aneuploidy for chromosomes 3,7, 9p21, and 17. Vysis is also developing similar FISH markers for lung cancer (LaVision).[6]

C. *Miscellaneous Tumor Markers*

Several other molecular markers in use or under development that may interest cytologists' include.[7]

1. **Lymphomas:** One of the oldest tests in molecular diagnostics utilizes the Southern Blot approach to search for gene rearrangements/translocations useful in the diagnosis of lymphomas. A PCR-based assay for follicular lymphoma reveals the t(14;18) translocation (bcl-2) and mantle cell lymphoma shows translocations t(11;14) with PCR on either tissue or cytology.[8,9,10] Kappa and Lambda light chain markers also have applications with ISH (Ventana, Inc.)

2. **FNA Applications:** There is a growing trend in FNA cytology to better classify genetic mutations that can aid the cytologist in stratifying aggressive versus less aggressive lesions. Although any of the molecular markers above that are helpful in triaging malignancies may apply to FNA cytology, a few additional markers are outlined below. At the current time, these markers are not routinely ordered by clinicians and are considered for research only (can not be reimbursed).

a. **Neuroblastoma:** N-Myc characterization using fluorescent in situ hybridization (FISH)**.**[11]
b. **Thyroid (papillary) cancer:** the RET tyrosine kinase domain (RETTK) using PCR.[12]
c. **Breast cancer:** Human androgen receptor monoclonality has been linked to breast cancer and reflex testing for equivocal or "atypical" breast aspirates (as well as ductal lavage) may have proven utility.[13] Loss of heterozygosity (LOH) of p53 oncogene mutations are found in 50% of all human cancers, including up to 80% of breast cancer (17p13.1) and colon cancer. [14,15] The p53 protein normally suppresses cell growth, but when mutated, allows for uncontrolled cellular growth with an often-fatal clinical course. Although there is currently an immunohistochemical test for p53, there are future PCR-based implications and current genomic microarrays with assess mutant p53.
c. **Pancreatic cancer:** K-*ras* mutations are seen in 90% of pancreatic carcinomas and up to 80% of cholangiocarcinomas.[16,17]
d. **Effusions:** FISH analysis for chromosomes 3, 8, 10, and 12 are being used to determine hyperdiploidy for equivocal or "atypical" cells.[18]

D. Serum Tests for Cancer Prevention: Future Cytologic Applications?

Currently, a number of tissue-based immunocytochemical tumor antigen tests are available as IVD's or ASR's including p53 and BRCA-1/BRCA-2 tumor suppressor oncogenes, p16 cell cycle proliferation/cyclin dependant kinase oncogene, and epidermal growth factor (EGF) angiogenesis inhibitor (Santa Cruz Biotechnology, Calbiochem, Inc., LabVision-Neomarkers Corp., DakoCytomation, Inc.). Although to date IHC is currently less expensive than molecular applications, the trend in clinical diagnostics is moving towards more sensitive PCR-based assays for clinically managing patients with aggressive or advanced cancers (breast, colon, melanoma, pancreatic, head and neck tumors).

1. **Breast and ovarian cancer (BRCA 1 and 2 genes):** There is a possible application with ductal lavage samples or FNA cancer-positive breast specimens (patients with BRCA 1 have a 60% 10-year risk of developing cancer in opposite breast and may opt for double mastectomy). BRCA1 mutations found in breast cancer patients are generally estrogen negative and patients many choose herceptin therapy over tamoxifen, whereas BRCA 2 mutations are exactly the opposite (ER positive). Currently, the analysis is a PCR assay (Myriad Genetics, UT).
2. **Colon Cancer:** Hereditary nonpolyposis colorectal cancer, an inherited syndrome (MLH1 *or* MSH2 *gene mutation)* and analysis of mutations associated with familial polyposis (FAP) and attenuated FAP is available with COLARIS *AP*[SM]*.* FAP and AFAP have also been associated with duodenal cancer, gastric cancer, thyroid cancer, hepatoblastoma, pancreatic cancer and CNS tumors. Currently, analysis is a PCR-based assay (Myriad Genetics).
3. **Melanoma and Pancreatic Cancer:** The *p16* gene mutation can be determined with PCR using MELARIS[SM] (Myriad Genetics).

E. Prognostic Markers

Although not all newer assays are nucleic acid-based tests, including p16 immunocytochemical protein expression (DakoCytomation, CA) for determining progressive cervical lesions (visualized via microscopy with LBP specimens), molecular tests are emerging in the laboratory at an accelerated pace. Tissue and chip microarrays are providing massive parallel information on gene expression, polymorphisms and mutation detections. Using laser microdissection from paraffin-embedded blocks, tissue microarrays contain many patient samples per glass slide, which is processed all at once using immunohistochemistry (such as bcl-2 staining for lymphomas) (Figure I).[19] In comparison, a gene chip microarray is designed to be a compact device that contains a large number of well-defined immobilized capture molecules (e.g. PCR products, proteins, or antibodies). One can examine where the specific molecule was captured by

exposing an unknown test substance on the microarray in order to derive information on identity and quantity of the captured molecule. Examples include analysis of p53 expression for use in evaluating lung or bladder cancer using the GeneChip® (Affymetrix) and *BRCA-1, BRCA-2* for breast cancer. [20,21,22,23] With GeneChip®, cDNA clones are robotically deposited on a glass slide and hybridized with fluorescently labeled probes (cDNA populations). A laser confocal fluorescent microscope is used to assess the intensity of the fluorescence, which is followed by image analysis. Information derived from microarrays help to determine which genes are highly expressed or under expressed. In the future, the goal is to determine if systematic gene expression patterns in human tumors can serve to improve the current taxonomy of cancer by illustrating "molecular portraits" or "molecular signatures" of cancer.

Conclusion

Although there are currently less than 40 FDA approved molecular assays available, revenues from molecular diagnostics already yield a one billion dollar-a-year industry, with exponential growth expected due to the emergence of new ASR's following completion of the human genome map. Thus, with the current speed of molecular assay development, cytotechnologists, who already serve as experts in diagnostic cytology and infectious diseases, should put themselves in the driver's seat by taking a proactive role in the implementation and interpretation of these new adjunctive tests. As cytology educational programs begin integrating these technologies into their curriculum, more of these tests should be performed by cytotechnologists in their respective laboratories. Cytotechnologists evolving competence in the area of molecular diagnostics will likely allow limited infectious disease and numerous oncology technologies to cross over from the clinical laboratory (sometimes performed by MTs or bench trained technologists) to the cytology laboratory. After all, these are the laboratory professionals that rendered the initial interpretation of the disease and possess the expertise to correlate the cellular and tissue interpretation with the latest adjunctive technologies. Hopefully, as these technologies begin to integrate into the cytology laboratory, hospital managers/administrators will understand the importance of cytotechnologists performing these tests (due to their knowledge-base in cancer diagnostics) and profit margins will sustain cytotechnologist involvement. So get on board. After all, "It's better to be behind the wheel of change, than under it."

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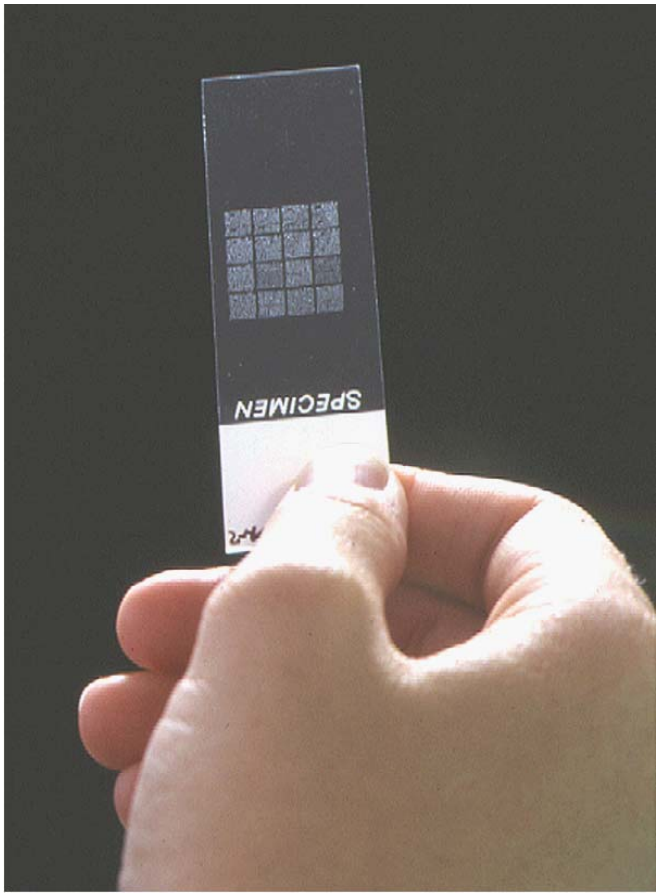

Figure I: Tissue Microarray (photograph courtesy of EP Diamandis, MD. (ACDC Labs, Toronto)

***Advance Organizer**:* This essay touches on the challenges of incorporating new and developing technologies into the cytotechnology curriculum. It offers many practical tips on how to provide learning experiences, utilize case studies, and obtain additional training in these techniques from rotation sites and other local laboratories.

Incorporating New Technologies into the Cytotechnology Curriculum: Using Experiential Learning, Including Distance Learning Activities and Case Study Materials – A Game Plan for Getting Started

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Introduction

The most recent update of the standards now indicates that we should include several new technology topics into our curriculum. At this point these include flow cytometry, diagnostic imaging, such as Ploidy studies as well as molecular diagnostics, which is becoming a critical topic for every program. The material in cytotechnology is already extremely long and exacting in all the areas of diagnostic cytopathology that students must master before graduating. Some educators feel that we have expanded the content to the maximum possible in a 12-month program. In addition, many educators feel we must seize the morphology based molecular techniques as a part of our professional practice since these techniques will likely replace some areas of cytotechnology as the profession evolves into the next decade. The rapid advances in laboratory diagnostic techniques require radical adjustments in the scope and practice of the cytotechnologist. These approaches have opened up whole new topics to be taught. It is imperative that we arm our graduates with the tools that will allow them to demonstrate the required expertise in these new areas of laboratory science. These new diagnostic tools and those not discovered yet, are rapidly becoming available to aid in the diagnosis and treatment of cancer, which is the professional purview of cytopathology and specifically cytotechnology.

There are several issues that need to be considered when incorporating additional topics, which are not specifically the classic cell morphology, into the cytotechnology curriculum.

These students are all adults and have made a career choice; they want to succeed in the program but also need to see the direct application of what they are asked to learn. Students come into the program from a variety of backgrounds in the sciences and so there could be opportunities for cooperative learning and tutoring within the class. Educators need to embrace the true meaning of their titles as “Program Director or Education Coordinator” and give up the idea of being the expert in the classroom. We will never be as comfortable with these topics as we are with the cell morphology concepts we were trained in and use every day. We are learning these techniques along with the students. These new technologies are changing quickly and others are constantly being added. We cannot hope to have a broad and deep understanding of all of this before introducing it into the curriculum. We must reach out into the medical and laboratory community around us and bring in the expertise to help our students and faculty learn what we need.

Materials

Faculty must accumulate a wide variety of introductory material for these topics. Since this information is in constant flux, a collection of web sites and current articles from cytopathology literature as well as information supplied by manufacturers should be considered. The CD ROM from Roche Diagnostics is a good example of manufacturer-created learning materials. The web sites for Ventana Medical Systems and Immunocyte, Inc. are good sources of material. Avoiding expensive textbooks, which can have a limited life expectancy, can save money for programs and students.

Instructional Materials

Can a CD ROM or reading assignments with appropriate web site reviews teach an understanding or appreciation of laboratory techniques sufficiently that students can demonstrate an understanding of the methods used and identify appropriate applications in a laboratory setting? Computer-based tutorials have

been a recent addition to the many allied health professional training programs. These types of learner centered, one-on-one instructional methods can be a critical tool in our small class size programs. Methods such as the workbooks of the Greenberg and Feifer (1980) study were a tool, integrating the teaching, application and reinforcement components of health care curricula. These tools help create a systematically integrated learning environment where the students can clearly see the links between theory and its clinical application. Tools such as the CD ROM, readings and web sites help to create an environment where real world experiences can be related to the ideas introduced in the classroom and then reflected upon in the development of case study scenarios. The TAR workbooks of Greenberg and Feifer had a very positive response from graduates who had used them. Bukowski (2002) shows in her study concerning a gross anatomy course that students in this physical therapy program where a computer-based experience replacing a hands-on laboratory showed no difference in performance as measured during clinical experience or on the national board exam. "Since the late 1980s, cognitive scientists, educators and technologists have suggested that learners might develop a deeper understanding of phenomena in the physical and social worlds if they could build and manipulate models of these phenomena. These speculations are now being tested in classrooms with technology-based modeling tools." (Bransford 2000, p. 215) There are previous incidents of science courses using computer-based simulations to duplicate actual laboratory work, which have shown positive results for students.

Experiential Learning

How can experiential learning methods be used to create a realistic learning activity? The allied health care professions have always had a strong component of "learning through practice" in all their programs. Most health care training had its historic origin as an apprenticeship training rather than a formal didactic education. With the adult students in the cytotechnology program it is important to create a close proximity of the working environment so that they remain focused and motivated to learn. As Raizen (1994, p.69) is quoted in Beckett's study done with the staff in a dementia unit (2001), "The evidence is strong that learning and motivation for learning are mediated through activities embedded in a context that makes sense and matters to the learner. Because learners have different backgrounds, it follows that not all contexts are equally effective for all learners or for all types of learning." (p.144) An experiential activity that can be directly related to what these students are shadowing in clinical rotation activities will help to make this connection. Within the faculty designed learning activities, assignments that simulate applying these techniques can also easily be incorporated. The student must complete the activity correctly, and communicate with the faculty at each step of the process. "Experiential education is changing because of downsizing and restructuring of health care institutions where clinical training has occurred. The shift of care from acute, institutional care to chronic, ambulatory care is having an enormous impact on locating teaching sites. Information technology has broadened avenues of personal interaction; it offers the possibility to facilitate patient communication, faculty mentoring, and professional education." (Commission to Implement Change in Pharmaceutical Education Paper 1996, p.380) The use of computer simulations to supplement clinical activities for students in training for a variety of fields is becoming an accepted practice. Cytotechnology has stubbornly clung to its traditional approach of placing a student with a practicing professional in a laboratory setting as its only experiential learning activity. I propose that we need to move into a multi-modality approach to experiential learning that will allow us to expose our students to a broad base of techniques and advanced methods that may not be available in a practical setting in our location.

Hands-on Laboratory Experience

Is it feasible and absolutely necessary to include an actual hands-on "wet lab" exercise for the experience to be a meaningful learning activity that relates to what the student will face at work? There may be opportunities for the students to visit laboratories where several of the new techniques they have learned are being done. If they cannot have an extended experience, at least they can observe and interact on a limited basis with professionals who are using these new diagnostics. Reaching out into the community has become a necessity in order for us to provide a wide variety of experiences for all our students. As an example, the Genomics Institute at the New York State Department of Health has expressed an interest in giving our students a short, hands-on laboratory experience such as this. The manufacturers of these materials are also interested in visiting the classroom and giving our students a simulated hands-on laboratory experience. Studies cited by Bukowski (2002) as well as her own study showed no difference in

student performance on examinations or in their knowledge and skill as perceived by clinical instructors between the group who had computer-based instruction and those who had a cadaver course in human anatomy. (p.156) The study results cited by Bukowski in a similar adult learning situation may indicate that a computer-based course for the introductory level exposure to the new diagnostic techniques would be sufficient, especially when combined with a series of experiential activities and case studies to simulate real life applications.

Case Study Approach

Can using a case study format convey the appropriate depth and breath of understanding? When using case studies in this context the faculty will try to emphasize the types of laboratory diagnostic scenarios where the new diagnostic techniques would be an adjunct to the cytopathology diagnosis. These techniques, such as immunoperoxidase staining, flow cytometry, DNA Ploidy studies and FISH, along with the basic molecular diagnostic techniques for HPV testing are currently used in many laboratories. Students must become familiar with how to interpret the results of the studies and when to ask for which type of study to be preformed. In many laboratories currently the ordering and initial interpretation of these techniques is in the purview of the cytotechnologist. Adding yet another modality, which can be an adjunct to diagnosing a patient's disease, is a logical outgrowth of these areas.

The case study format is a technique that educators in the health professions have used successfully for many years. Owens et al. (2002) provide a discussion of the case study method as a useful approach for teaching adult health care professionals. A well-developed case study has features similar to other instructional design plans, such as those seen in problem-based learning. Using case studies can facilitate the differentiation of core knowledge from its application, give an opportunity for the learners to move at their own pace, and give them a safe environment to practice the application of knowledge and critical thinking skills in clinical settings. (p.478) These activities can offer students the chance to self regulate their learning, to go back, correct mistakes and evaluate where they need to review the instructional materials.

The case studies incorporated into the curriculum design by the faculty will prepare the students to work on the case studies in the distance learning activities and finally to develop their own case study to be presented to their classmates. "Clinicians may be better able to apply and remember knowledge when this information is framed with a clinical case rather than presented in a didactic lecture, because the context is relevant to their work experience."(Owens et al, 2002, p.478) It will be important to design cases, which relate to the knowledge already gained by the students and to demonstrate how this new knowledge will increase their abilities in the work place.

With adult learners during the final months of their educational experience, it is necessary to make direct connections for students to see a benefit and invest the time needed to successfully complete this unit. "Examining only cases of successful change, they (Fox et al 1998 in Borduas et al, 2001) noticed that the greater the gap between the current and the desired situation, the greater the effort made to learn. Furthermore, when the main motivation for change was greater competence, learning was more likely to be directed toward clinical problem solving and the use of first hand experience." (p.104) This study by Borduas et al demonstrated a significant increase in posttest knowledge as well as a high satisfaction rate with the case study approach, which they used with health care professionals as a continuing education activity. Case studies bring a real world experience into the classroom and offer a way to create real life clinical situations for students to practice their skills without the stress of actual patient care situations.

Case study scenarios can be transmitted to students in sections via E-mail for those programs that do not have the software available for on-line courses. Thus the student would be given an initial patient history, and photomicrographs of the cytologic specimen. The student would return a preliminary diagnosis to the faculty with a request for which additional studies should be done. Faculty would have to prepare lab results for each possible correct and reasonable non-correct response. The requested information with photomicrographs could be returned to the student. Based on this information they could again request additional studies or confirm their correct diagnosis and describe how the requested techniques applied supports this.

Instructional Time Allocation

What time will such activities take and can this be justified in an already over crowded curriculum? The curriculum for the cytotechnology program is based on the standards and guidelines set by our accrediting agency. There are no topics that could be eliminated without jeopardizing a student's chances to pass the BOR. These ancillary techniques are very new areas of laboratory science, and the rate at which scientific advances go from research to clinical application has increased exponentially in the last decade. These rapid changes in the tools of the profession require a rapid response from educators if the profession of cytotechnology is not to be shut out of these new modalities and become obsolete. By offering this topic as an "extra" or elective unit, students who are feeling overwhelmed by the core curriculum could opt-out of the new diagnostic techniques unit. These students could still sit for the national registry exam in cytotechnology, but would require additional training to take the exam in Molecular Pathology. As it currently stands, the national registry exam in Molecular Pathology is open to registered Cytotechnologists and Medical Technologists. Students who opt out of the elective unit can study the material and sit for the exam anytime after graduation.

In the study by Williams et al (1995, p. 163) students in the occupational therapy and physical therapy programs reported a significant drop in the time they spent actively studying during the clinical experience portion of their programs. In many existing programs, the cytotechnology students are involved in a working laboratory environment for a normal eight-hour day during the final three months of the program. Their study time is also likely to be drastically reduced, since all major topics have been covered during the didactic portion prior to the beginning of clinical rotations. The new diagnostic techniques unit, which can be a self paced learning experience, could be scheduled during this time without severely compromising the students time spent on other topics.

Assessment

How can the learning be assessed? Assessment for experiential learning, even when case study materials are used can be problematic. There are subjective elements to any evaluations done on a student's performance during a self-paced, problem solving learning experience. Evaluating the performance of students during any clinical laboratory experience can be difficult. Clinical instructors are often not comfortable with giving critical evaluations of students they have grown to know personally. Also personality conflicts can color an evaluation where observation of performance in a real world setting is the tool of choice. These problems are addressed in the article by Beck (1995) "Evaluating Student Performance in the Experiential setting with Confidence". Beck points out that evaluators of clinical performance need to be provided with appropriate training as evaluators. Preceptors need to identify the differences between performance standards for novice practitioners and experts.

As the faculty develops case studies they need to evaluate the level of skill expected by the student at that point in the program. As evaluation standards are designed for the student's own case study, clearly identified goals and objectives need to be conveyed. A "scaffold" or outline for the student to use in constructing the case study should be provided. Students should be given an opportunity to submit "rough draft" copies of their work for evaluation and direction. Gist (1992) recommends in her review of problem based learning techniques applied to environmental health education programs, that evaluation of problem-based learning involve the integration of several evaluation techniques. "Traditionally, assessment of learning has emphasized factual information. However, since problem-based learning also stresses scientific reasoning, acquisition and integration of knowledge, peer support, teaching and communication skills, group interaction, and assessment of one's self and one's peers, these areas should be given equal consideration with respect to academic appraisals." (Gist 1992, p.10)

The final method of evaluation should be a type of self-evaluation that provides a method of reflection on the learning. With adult learners it is possible to get a great response to reflective activities. These are students who are very motivated and, when shown the importance of an activity, are eager participants. In Wilson's study (1999,) of working laboratory managers, the use of "research diaries," even by busy clinicians, was viewed as an opportunity for growth. She recommends three stages of progression: "1. participants developed their awareness of the problems (reconnaissance); 2. examined their own attitudes

(reflection); 3. undertook managerial actions (action steps)." (p. 8) This is similar to what can be expected for the cytotechnology students as they keep a journal of their efforts in the new diagnostic techniques unit and share some of these journal entries with their classmates. The final action step would be the development of their own case study and the presentation of this to the class.

The Instructional Design

The instructional design can be broken down into its component parts. Since this will be a complete unit of the cytotechnology program, there will have to be sources for students to obtain background knowledge and a sequence of activities for them to accomplish. There will have to be identified goals and objectives as well as measurable outcomes and tools for assessment.

Information sources:

1. A collection of web sites by both manufacturers and medical diagnostic technologies.

2. Current articles from peer review journals in cytopathology, *ACTA Cytologica*, *Cancer Cytopathology and Diagnostic Cytopathology.*

3. Informational literature from the manufacturers of these new technologies are currently available.

4. A dictionary or glossary of terms should be collected by faculty and supplied to students.

Sequence of activities:

1. Students will first complete the CDROM-based, web-based or written introductory material on the new technologies and successfully answer any questions imbedded in this material. This activity should take approximately 8 hours of time at the computer or in reading printed material.

2. Students will answer a test developed by faculty to assess their knowledge of this material. There will have to be an assessment at this stage to insure that students have grasped the basic background information needed to complete the next phase. A short answer test can be administered when students identify themselves as ready. They can return to the classroom or take it as an on-line test at the cytotechnology program web site, or by e-mail.

3. Students who successfully complete the test will be given three case study exercises developed by faculty. To evaluate the students' understanding and application of the new diagnostic techniques, case studies will be developed that can be presented in an interactive format. The students will first be given a patient history and photomicrographs of the cytologic specimen. They must indicate which of the new diagnostic methods should be used and why. After requesting this information, they will be given the test results. They are then to formulate a final diagnosis for this case, or request further studies before rendering the final diagnosis. This final report of the case should include a discussion of how the new techniques assisted in the final diagnosis and the strengths and limitations of the cytomorphology for this case.

4. Written responses to the case studies will be required. These can be done though e-mail as they are given information, request further studies and then get a response from faculty. All students must successfully complete three case studies before proceeding to the next step.

5. Students will develop a case study of their own, which demonstrates the use of at least one of the diagnostic techniques (covered in the introductory material) in the cytopathology diagnosis. These can be modeled on the studies they have completed; they can use either patients from their clinical rotation site laboratories or cases given to them by the faculty from the school files. Faculty will be available to review and guide the development of these cases. No student will present a case, which has not been reviewed and approved by the faculty. Students must comply with all regulations concerning patient confidentiality.

6. Students will participate in a seminar session during the final weeks of the program where they will present their case study. The student will prepare a Power Point presentation of their case study. They will take photomicrographs of the cytology specimens, give appropriate patient history and identify the new diagnostic techniques to be used and why. They will show how these techniques are done in the laboratory and what the final results are for this patient. They will explain how these results add to the final diagnosis and how this affects patient care.

7. The faculty and the other students will evaluate each student's case study. Evaluation forms will be provided that give rubrics for grading. The grades given by students will be combined to equal 1/3 of the total grade for this part of the unit. These rubrics will be made available to the students as they prepare their case study.

8. Students will keep a journal of their thoughts and ideas as they progress thorough this unit. This journal will be an opportunity for them to reflect on their learning and will be shared with the faculty as part of the evaluation for this unit. Students can e-mail copies of their entries to the faculty and keep a copy for themselves. In reflective journal writing, it is important for the students to retain the journal so that they can review their progress.

9. Final grades for this unit will be based on 20% test, 20% responses to the case studies provided, 20% reflective journals and self evaluation of the learning, and 40% on the student's own case study and its presentation.

Goals and Objectives for the New Diagnostic Technologies Unit

1. Recognize all of the major technologies covered in the materials supplied.

2. Discuss the basic theory behind each technology.

3. Apply the appropriate theories to the case studies presented.

4. Use these theories and techniques to develop an original case study.

5. Present their case study to the class in such a way as to convey their knowledge and understanding of the selected techniques and theories that apply.

6. Articulate the appropriate application of each of the new diagnostic techniques in the cytopathology laboratory.

Conclusion

There are ever increasing pressures on cytotechnology programs to incorporate more material in the same instructional time. We need to embrace methods that will bring flexibility and a more self-directed learning approach to our professional training programs. The adult learners in this health care field are eager to take responsibility for their learning; as educators, we need to let this happen. Setting rigid expectations for each student's clinical experience limits the amount and type of opportunity we can offer them. "Reinforcement of bad technique necessitated by poor equipment and facilities does not benefit the student, the patient or the profession." (Strickland 1996, p.25) The research study by Bukowski (2002) demonstrates that using a CD ROM in place of a hands-on experience can convey the required knowledge base for students in a Physical Therapy program. Further research is indicated to follow up on the test scores for students who are involved in these activities as their introductory training module.

The possession of a body of knowledge about science is not an adequate achievement for the student today. Today's aim is to get the student away from the misleading image of science as an absolute, complete and permanent. In order to achieve this aim, the teacher sets the stage for a mind-set of inquiry by

posing the problems, creating a responsive environment, and giving assistance to the students in the investigative operations. (Rogers 1994, p. 205)

By creating an experiential learning environment that uses a series of case study activities, I feel that we can adequately simulate a real world experience for the student. Isn't this what we do each day with every unknown slide they screen? They will need an opportunity to selectively apply the knowledge learned. Not all students may be able to attend actual clinical laboratory experiences where these techniques are in use. The research by Bordeas et al (2001) using a longitudinal case study in training physicians has shown promise for replacing real patients with the case study model and achieving the desired learning goals with the participants. This method also will allow some flexibility and can adapt to this fast changing field as new techniques are approved for the cytopathology laboratory.

Adding an area of new methodology for cytopathology diagnoses can only enhance the opportunities available to our students upon graduation. Beyond any given body of knowledge, the core of professional training is to indoctrinate new practitioners into the methods, means and thought processes of those who are members of that profession. As Coles (2002) quotes Carr, "Professionalism is not just any kind of work [it] is esoteric, complex, and discretionary in character; it requires theoretical knowledge, skill and judgment that ordinary people do not possess, may not wholly comprehend and cannot readily evaluate…The work they do is believed to be especially important for the well being of individuals or society at large, having a value so special that money cannot serve as its sole measure…It is the capacity to perform that special kind of work which distinguishes those who are professional from most other workers." (p. 8)

Advance Organizer: This essay explores the basic *who, where, when, why* and *how* issues related to retraining cytotechnologists. Many of our cytology training programs have received numerous requests concerning retraining cytotechnologists. With no concrete established rules and guidelines concerning retraining, many programs are unsure how to tackle such an issue. Programs can easily look within the framework, techniques and guidelines of their existing cytology training programs to provide the education necessary in retraining cytotechnologists. Unlike our standard training programs, retraining is often more focused and specialized towards specific problems. However, the teaching techniques and strategies employed for our cytology students can work equally well for cytotechnologists in need of retraining.

Retraining Cytotechnologists

Maria Friedlander, M.P.A., CT(ASCP)

WHO:

For the past six years, our laboratory has been approached to "retrain" cytotechnologists (CT) in gynecologic cytology. In some cases, "retraining" was requested because supervisory personnel were of the opinion that the CT's performance had strayed to a sub-optimal level. Workshops and lectures had not been enough for these individuals to sharpen their criteria, update their skills and utilize current terminology. Retraining was an option that their employers chose to try to get these CTs back on track.

Retraining is not only for CTs who fail to demonstrate competency. It is an opportunity for CTs who are changing jobs or examining new types of specimens to review cytologic material that will be expected to be part of their workload. Cytotechnologists who have been away from the field and want to resume working can also benefit from retraining.

WHY:

Why should we even bother or be concerned with this issue? Unfortunately, the current shortage of CTs in certain areas of the country and the decreased enrollment in CT training programs is an issue that revisits us today after 14 years. The field of cytology cannot afford to lose CTs when such a shortage exists. Retraining offers an opportunity to retain the CTs we already have and to assist them in improving and maintaining their skills.

WHERE & WHEN:

Retraining needs to take place in the appropriate facility with suitable instructors. In our laboratory, retraining is conducted by the Education Coordinator, however, Program Directors and clinical instructors with experience in teaching can also participate in retraining activities. The laboratory has an extensive collection of gynecologic and non-gynecologic glass slide teaching cases, including Thin Prep® preparations and fine needle aspirations. Additional educational resources include a comprehensive cytology library, CD ROMs and a large kodachrome and digital image collection. A double-headed microscope is available and dedicated to retraining activities during the retraining period.

If possible, scheduling retraining in conjunction with your cytology school schedule will be most advantageous. Also, scheduling retraining in the summer months when the cytology students are doing their clinical rotations also allows the trainer more time to dedicate towards retraining efforts.

HOW LONG:

The length of retraining varies but usually lasts about one to two weeks, depending on the length of time the CT and employer have available. The more time the CT can dedicate to retraining, the more likely it will be effective.

HOW:

In our retraining program, each CT's training is targeted to the individual's specific problems or needs. There are a number of different steps involved in the retraining process (**TABLE 1**). These include identifying the problem(s), reviewing established criteria and monitoring performance. Post-training activities, which take place in the trainee's laboratory, are also necessary and allow the CT to apply and practice what was learned during the retraining period.

TABLE 1: RETRAINING ACTIVITIES

Assess Problem
- Identify specific problems
- Administer pre-test

Establish Criteria
- Assign appropriate reading
- Assign glass slides for independent review
- Conduct didactic microscopic sessions

Monitor Performance
- Administer self-assessments daily
- Administer post-test

Post-Training (in trainee's laboratory)
- Decrease workload
- Rescreen slides to evaluate performance

RETRAINING ACTIVITIES:

1. PROBLEM ASSESSMENT

In most cases, the employer and CT will have previously identified specific problems prior to the retraining period. A pre-test, consisting of a range of diagnostic entities, is also administered to identify any further difficulties. Some of the more common problems that CTs requiring retraining have include:

- Detective errors
  - identifying significant cells when few cells are present
  - missing significant cells entirely
  - missing small CIS cells
- Interpretation errors
  - Reactive vs neoplastic cells
  - ASCUS vs. LSIL vs. HSIL
- Slow screening speed
- Unfamiliarity with most recent updates of the Bethesda System

2. RE-ESTABLISH CRITERIA

For all trainees, basic cytologic criteria is first established by assigning reading concurrent to examining cytologic slides from the teaching collection. The CT works independently at first. Subsequently, cases are examined one-on-one with the trainer at a double-headed microscope to see if the CT is using the correct terminology and criteria to identify appropriate cytomorphology. A discussion of differential diagnoses is incorporated in these review sessions, and criteria that distinguish entities from one another are emphasized. Didactic microscopic sessions are conducted daily with the trainer to evaluate the CT's progress. Homework may also be necessary such as additional reading and evaluation of unknown kodachrome images.

3. MONITOR PERFORMANCE

Daily self-assessments are administered to monitor performance. Each self-assessment includes cases specifically targeted towards the CT's weak areas. Cytology schools should use the unknown cases and glass slide examinations they employ for their students. The same standards and guidelines that define competency for their cytology students can be employed for their trainees. More difficult cases should be seeded into the self-assessments as the CT shows improvement through the course of the retraining period. A post-test is administered at the completion of retraining to assess the CT's overall progress. Didactic microscopic sessions need to be conducted on a daily basis to monitor performance, review problematic cases and suggest strategies for improvement. Some of the strategies used to improve on locator and interpretive skills are outlined below. Most of them are likely familiar to you and ones you have used in your own programs on your students:

STRATEGIES TO IMPROVE DETECTOR / LOCATOR SKILLS

- Have retrainee screen cases where only few atypical cells are present.
- Have retrainee watch trainer screen and vice versa at a double-headed microscope.
- Recognition of cell patterns.
- Suggest appropriate figures for screening overlap and screening time.

STRATEGIES TO IMPROVE INTERPRETIVE SKILLS

- Have retrainee write down the criteria for significant cells in the cases they screen.
- Have retrainee orally describe criteria they see during didactic microscopic sessions.
- Emphasize comparison of cytologic findings to normal markers.
- Compare unknown cases to known cases.
- Incorporate differential diagnoses in daily self-assessments.
- Have retrainee provide a list of differential diagnoses for each case.

4. POST-TRAINING

Detection and sensitivity problems are difficult to resolve completely in one to two weeks. Subsequent to retraining, post-training activities need to take place in the trainee's laboratory. This allows the CT to practice and strengthen the knowledge and skills acquired during retraining. These activities include reducing and rescreening the CT's workload. With improvement, the workload can be gradually increased to a more appropriate level. The availability of resources, such as time and staffing, that may be needed to support post-training activities are important issues for employers to consider when sending CTs for retraining.

Our experience with retraining has been successful in some cases and less promising in others. In the successful cases, the CTs recognized that they had a problem, were receptive to improving themselves and worked hard. The laboratories valued their employees enough to send them to a place where they could work at doing this. Upon returning to work, the employer also provided the time and resources that allowed the CT to apply what was learned during the retraining period. The venture was successful.

In a few other cases, however, retraining was not as encouraging. Retraining was less successful because the laboratory could not provide additional resources in the post-training period. Perhaps if more time were dedicated to the retraining effort, results would have been more successful. Also, in some other cases, personal problems interfered with the CT's ability to concentrate in general.

This was demonstrated in their performance. These CTs showed improvement in their skills during the retraining period, but no retraining program can help a distracted CT. When these individuals returned to work, they were either relocated to other positions in the laboratory or left the field altogether within a short period of time.

It is important to realize that retraining may not work for everyone. Self-assessments and review of teaching cases do not mimic the real world of screening. Assuming that a "new and improved" CT will return to work after just two weeks is a high and improbable expectation. In most cases, the laboratory and CT will need to work together in the "post-training" period on the strategies learned during the retraining. Not all laboratories have the time or staffing to do this.

Cytotechnology education has come a long way. Our curriculum has expanded to include a comprehensive list of basic entry-level competencies. However, cytology education not only involves breeding new CTs, it also involves educating professional CTs in search of refreshening their skills and learning new ones. Cytology educators are capable of participating in this with the knowledge and special skills that they possess.

Continuing education is an integral part of our professional development as CTs and is essential to quality patient care. We attend national and local meetings to learn from experts on a variety of topics in various settings. Some prefer formal lectures using illustrative transparencies while others prefer microscopic workshops. We read journals and books to keep abreast of the latest research findings and current terminology. In the future, our education will probably also include telecytology via the Internet. But sometimes a one-on-one approach to remediation may be more useful and rewarding.

Advance Organizer: Undoubtedly the most important role of a cytotechnology educator is to teach microscopic skills and to be able to evaluate the development of those skills in our students. This essay is presented to provide one method for evaluation of cytotechnology student performance at the microscope. No standard method for evaluating microscopic performance has been determined for cytotechnology education due to variations in the clinical training portion among the different programs. Those variations include factors such as the length of the clinical portion of the program, the laboratory setting, laboratory caseload, the amount of time (hours in a day, number of days, number of weeks) assigned to the clinical training portion and the number of clinical faculty assigned to grading students. The method presented here is the culmination of the efforts of many faculty over many years working within the confines of a university grading system. It is not perfect and has been adjusted over the years in concert with other outcome measures such as registry exam scores and input from employer evaluations of graduates. It has provided us with a framework for determining competence of our students and a basis for planning areas for improvement as they progress through the clinical portion of their training.

Microscopic Skill Evaluation

Barbara D. Benstein, Ph.D., SCT(ASCP)

Introduction:

Microscopic skills include both detector skills and interpretive skills. Detector skills are based on the student's ability to recognize and detect cells that are "not normal" and are dependent upon the student's knowledge of normal cellular morphology. Interpretive skills require the ability to evaluate and formulate a differential diagnosis after analyzing cytologic findings within the context of pertinent clinical data. Interpretive skills entail more than just the ability to recognize cellular findings as abnormal; they necessitate arriving at a specific diagnosis or interpretation.

Detector skills are measured by calculating the false negative rate or false negative fraction in order to determine the student's diagnostic sensitivity rate.
For cytotechnology students, their diagnostic sensitivity is defined as the percent of abnormal cases they correctly identify as abnormal. In this instance, it does not matter if the exact specific diagnosis is not given, provided the case is recognized as abnormal to facilitate appropriate triage.

Interpretive skills are determined by how precisely the student's interpretation of the cases matches the final diagnosis. The student's accuracy rate is dependent upon the percentage of normal cases they identify correctly as normal (specificity) as well as how precisely they identify the abnormal cases.

Early in the curriculum, we emphasize detector skills so a greater portion of the student's grade is based on their sensitivity rate. It may be as much as 50% of their grade with the other 50% based on accuracy rate. Later in the curriculum, we expect our students to develop higher cognitive skills and be more specific in their interpretations. By the end of the program, students are expected to meet a minimum sensitivity of 90% in order to pass the clinical practicum portion and to have their grade calculated for the course. The actual grade that students receive for the practicum is based exclusively on accuracy of interpretation. A minimum accuracy grade of 70% is required to pass and graduate from the program.

Definition of Errors:

It is important for students to understand what constitutes an "error" and how errors are defined. There is much disparity in the cytology literature as to what should be considered a "false negative". This is left up to the laboratory to be determined and may be decided upon relative to many factors such as volume and patient population (e.g. high risk). In our program, the definition of a false negative is slightly different in the early part of the curriculum as opposed to later in the curriculum. A **false negative** in the first semester is defined as any case of ASC-H and LSIL or higher that a student calls negative. If a student misses an ASC-US, it is considered an **undercall** rather than a false negative. However, in the last semester, a false negative is any abnormality (ASC-US, ASC-H, and LSIL or higher) that a student calls

negative. Given the exception just mentioned, the following is a chart that defines the different types of errors as identified during the clinical practicum in the final semester of the program:

Microscopic Evaluation
Definition of Errors

Type of Error	Student Interpretation	Final Interpretation
False negative:	Negative	ASC-US, ASC-H, LSIL & above
False positive:	CIS or invasive cancer	Negative or unsatisfactory
Undercall: 2 steps or more under an abnormal diagnosis or:	unsatisfactory	HSIL & above
Overcall: 2 or more steps* over a diagnosis	e.g.: HSIL, mod dysplasia e.g.: HSIL-CIS	Negative or unsatisfactory LSIL, mild dysplasia
Mild undercall: one step under an abnormal diagnosis	e.g.: HSIL-CIS or: Negative	Invasive cancer Unsatisfactory
Mild overcall:	LSIL or unsat LSIL, mild dysplasia ASC-US	Negative Unsatisfactory Negative

Miscellaneous errors: failure to identify organisms or other inconsistencies, failure to mark enough cells, failure to otherwise handle the case appropriately; etc. Examples are too numerous to list.
*Students are not penalized for one-step overcalls.

Collection of Student Performance Data:

Students are required to record all cytologic cases evaluated on a daily basis using the form below. This provides a record of their interpretation as well as the final interpretation of the case either by a pathologist or by a certified cytotechnologist in the case of a negative gynecologic specimen.

University of Tennessee Health Science Center
543 CT Cytology Practicum
Prescreening Microscopic Evaluation Form
Clinical Rotation Site: _____

Student Name: **Date**:

Slide #	Specimen Type	# of slides	Description	Adequacy	Student Dx	Final Dx	Error type

Total # slides evaluated: _____

Students are also required to complete a daily workload record of the number of slides evaluated (screened) and the time spent in microscopic evaluation of unknown slide material. We also monitor what other activities are being performed at the clinical sites. Using the data collected in the form below, we can assess productivity by computing how many slides per hour our students are evaluating. The record must be give to a faculty member at the end of each week.

University of Tennessee Health Science Center
543 T Cytology Practicum
Cytotechnology Student Workload Record

Student Name: _____

Date	Day of week	Hours spent screening	# of slides screened	Other duties
	Monday			
	Tuesday			
	Wednesday			
	Thursday			
	Friday			
Totals				

Productivity (slides/hour): $\frac{\text{total \# slides screened}}{\text{total \# hours spent screening}}$

It should be noted here that there has been no nationally recognized standard minimum number of slides that a cytotechnology student must be able to evaluate by the end of their training program. However, based on a survey conducted by a CPRC Task Force on Measuring Student Microscopic Performance, the range of slides required by cytotechnology programs was 5-10 slides per hour and 40-60 slides per day. The most frequent response by the programs was 6 slides per hour and 40-45 slides per day.

Summary of Student Performance Data:

Prescreening forms are collected from the clinical instructors for each student at all the clinical sites on a weekly basis. The data from these forms is summarized into the following table so the types of errors can be readily assessed and any trends immediately noticed so plans to improve performance can be implemented quickly.

University of Tennessee Health Science Center
543 T Cytology Practicum
Microscopic Evaluation Summary Sheet

Student Name: _____

Week of:										total
total abnormals										
false negatives										
false positives										
undercall										
mild undercall										
overcall										
mild overcall										
miscellaneous										
itemized misc										
Total slides										
Average #/hour										
Average #/day										

Each case that students evaluate during the clinical practicum is also plotted on the graph below so student interpretations can be compared to the final diagnosis on the cases they have evaluated. Cases that plot along the diagonal are considered to match or correlate well with the final interpretation. Cases that fall to the right and above the diagonal are overcalls or false positives. Cases that plot to the left and below the diagonal indicate false negatives or undercalls. The graph provides a quick means of assessing where students need help.

STUDENT INTERPRETATIONS

Final Diagnosis	Neg	Unsat	ASC/AGC	LSIL	HSIL-mod	HSIL-sev/CIS	Inv Ca
Neg							
Unsat							
ASC/AGC							
LSIL							
HSIL-mod							
HSIL-severe/CIS							
Inv Ca							

Calculation of Microscopic Performance Grade:

The following information is summarized from the forms completed by the students:

Total number of cases evaluated = _____
Total number of abnormal cases (false negatives & true positives) = _____
Number of false negatives = _____
Number of abnormal cases interpreted as abnormal by student = _____
Total number of negative cases = _____
Number of negative cases interpreted correctly by student as negative = _____
Total number of abnormal and unsatisfactory cases = _____
Number of abnormal and unsatisfactory cases correctly interpreted by student to within one degree of specific diagnosis = _____
Total miscellaneous errors = _____

The following calculations are made based on the summarized data:

Sensitivity: percentage of the number of abnormal cases correctly interpreted as abnormal (even if the interpretation does not exactly match the final diagnosis)

Sensitivity = # of cases interpreted correctly as abnormal X 100 = _____%
total # of abnormal cases

Students must attain a minimum of 90% sensitivity in order to pass the practicum/course and have their grade evaluated in terms of accuracy.

Accuracy of interpretation: percentage of the number of cases correctly interpreted to within one degree overcall of the final diagnosis (with the exception of ASC, AGC or LSIL interpretation on a normal slide which is considered a mild overcall); no undercalls or false negatives are acceptable.

Accuracy for normals: $\frac{\text{\# of cases interpreted correctly as normal}}{\text{total \# of normal cases}}$ **X100=____%**

Accuracy for abnormals & unsats: $\frac{\text{\# of cases interpreted correctly}}{\text{total \# of abnormal \& unsat cases}}$ **X 100% = _____%**

Total accuracy = $\frac{\text{\% accuracy for normals + \% accuracy for abnormals \& unsats}}{2}$

Miscellaneous errors:
100 ÷ total # of cases = _____ ÷ 4 = _____ X # of miscellaneous errors = Y

Final Microscopic Performance Grade:
% total accuracy – Y = microscopic performance grade

Final Course Grade:
In our program, the final grade for the practicum course also includes a professional component. A comprehensive professional development evaluation is completed by clinical faculty on each student relative to their behavior, communication skills, responsibility, organizational skills and other attributes.

The student's final course grade is calculated as follows:
microscopic performance grade (3/4) + professional development evaluation (1/4) = _____%

All of the following must be met in order for students to pass this course and graduate from the program:

*a minimum of 90% sensitivity and 70% accuracy of interpretation on cytologic case material
*a grade of 80% or higher on the professional development evaluation
*a grade of C or higher in the course

Grading Scale:

93-100%	= A
85-92%	= B
77-84%	= C
70-77%	= D
69 and below	= F

Sample Calculation:

The following is a sample of how one student's microscopic performance grade was calculated using the system outlined above for a 4-week period in the practicum portion of our curriculum:

Total number of cases evaluated = **1782**
Total number of abnormal cases (false negatives & true positives) = **236**
Number of false negatives = **9**
Number of abnormal cases interpreted as abnormal by student = **227**
Total number of negative cases = **809**
Number of negative cases interpreted correctly by student as negative = **757**
Total number of abnormal and unsatisfactory cases = **253**
Number of abnormal and unsatisfactory cases correctly interpreted by student to within one degree of specific diagnosis = **218**
Total miscellaneous errors = **18**

Sensitivity = $\frac{227}{236}$ X 100 = 96.19%

Accuracy for normals: $\frac{757}{809}$ X100 = 93.57%

Accuracy for abnormals & unsats: $\frac{218}{253}$ X 100% = 86.17%

Total accuracy = 93.57 + 86.17 = 179.74 ÷ 2 = 89.87%

Miscellaneous errors:
100 ÷ 1782 = 0.06 ÷ 4 = 0.02 X 18 = 0.36

Final Microscopic Performance Grade:
89.87 – 0.36 = 89.51