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TEACHING NEAR THE EDGE OF CHAOS

Dynamic Systems, Student Choices and Library Research

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ABSTRACT

This article is an investigation of the Dynamic Systems theory and its application to instruction and the learning process. Curricular suggestions are provided from the authors' collaborative uses of library instruction within university academic courses. These suggestions address the use of environmental (classroom) and task manipulations to provide students with choices within activities related to conducting literature reviews. A Four-Step Teaching Model, based on the "Ecological Task Analysis Model" (Davis and Burton, 1991), is also outlined; to give readers a step-by-step procedure to use when developing classroom curricula and delivery plans.

INTRODUCTION

Admonishments to integrate information literacy (IL) and library instruction into content area instruction have primarily had two premises:

1. Research can be viewed in a disciplinary framework, where students are familiarized with the community of scholars in a particular discipline (Fister, 1993; McMillen & Hill, 2005). Students with greater understanding of authors, publications, and ways of accessing research have greater success in the research process.
2. Other authors (Stripling, 1995; Pitts, McGregor, & Stripling, 1995) have suggested that significant learning in this area only occurs when it is integrated with content, where students consider the instruction to be a more authentic learning experience.

An ancillary benefit not often suggested in the literature is that librarian instructors may incorporate pedagogy used in other disciplines to improve their own teaching. It is the purpose of this paper to propose the application of dynamic systems theory in motor learning and motor development to the teaching of literacy

and library skills by librarians in the classroom. In this case, the authors (an instruction librarian and a physical education/health educator) have found that such applications have offered a valuable lens through which to view information-seeking instruction and to frame active learning activities. These applications enable instructional activities and assignments to engage greater student use of IL skills to research course academic content. This approach deviates from the standard "one-shot" presentation that still defines most IL/library instruction sessions, where librarian instructors, with one opportunity to expose students to the use of library resources, try to cover numerous search techniques. Rather, this approach requires the librarian instructor to design tasks that engage students in desired IL skills and expose them to designated library resources. The instructor foregoes much of the lecture and demonstration that takes place in more traditional classroom settings; learning occurs as students reflect upon their success (or lack thereof) in completing the assigned tasks, and as they brainstorm strategies for improving their search results. The instructor's role changes from that of content provider to curriculum designer (in designing appropriate tasks). Finally, the teacher serves a responsive role in the classroom dynamic system, providing instructional support to those students in need, providing more complex tasks to those students who quickly master the material, and immediately altering instruction according to the students' learning needs.

Review of Literature

Dynamic systems theory, as a model of system organization, has contributed to the understanding of functioning in many diverse areas. While potentially as mathematically complicated as one could want, the basic simplicity of dynamic systems models has enabled theorists and researchers to apply them in virtually every area of scientific investigation. With roots in chaos theory, dynamic systems models contain two important tenets. First, when disrupted, systems will self-organize; and second, the best, most efficient reorganization of any system will emerge from the edge of the chaos that any initial change has first produced (Seel, 1999). Whether the reorganization that emerges is the regular and predictable movement of solar bodies, the development of motor abilities in children, the development of cognitive/academic skills, or the reconfiguration of organizations and their management policies and practices, the new organization will reflect the best possible steady state of the system within its new state of being.

Beginning in the physical sciences (such as physics and engineering) and moving into the psychological sciences (such as psychology, human development and education), dynamic systems models have found a voice within most contemporary discussions. These models have done much to clarify processes and to present challenges to accepted theories and practices. In the model of dynamic systems that he called a "model of constraints," Newell (1986) proposed that three factors play a role in a person's motor development. These factors are the individual characteristics, or *constraints*, that an individual possesses; the constraints of the task that the individual is being asked to perform; and the constraints of the environment within which the task is performed. These three factors interact with each other in an initially chaotic way that ultimately leads the system to create a solution in which the best possible movement outcome emerges. The limits of the three areas and their interactions constrain the system. The system will be limited to only the best, most stable outcome possible within these limits. Figure 1 illustrates Newell's model.

Examples to illustrate the dynamic nature of motor performance can be obvious, subtle, and surprising. The individual brings physical abilities, skills and experiences to any movement situation. Different task demands (speed vs. accuracy requirements, trajectory, required force, etc.) can evoke different movement responses, whether throwing, jumping, or running, or performing sport-specific skills (pitching, serving, shooting, etc.). Changes of the environmental demands (available space, size, distance and/or height of

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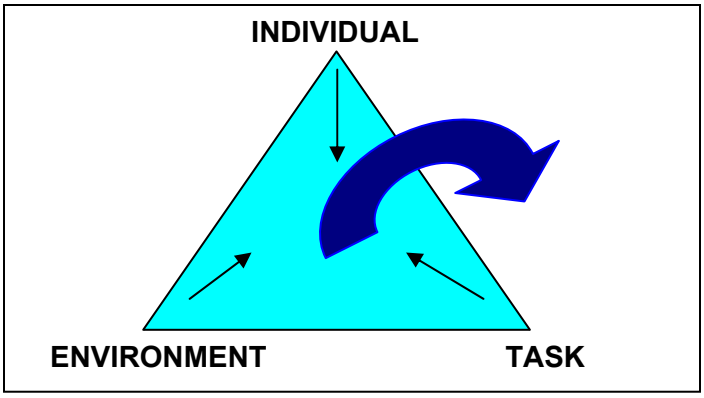
FIGURE 1 — DYNAMIC SYSTEMS INSTRUCTIONAL MODEL – MODIFIED FROM NEWELL (1986)



a target, texture of the surface, presence of lack of movement in the environment) or the equipment to be used (weight, size, length, texture) will evoke or facilitate varied movement responses.

Given a surface to move upon (e.g., a front lawn) and a task to perform—"move from Point A to Point B"—a newly walking 13-month-old child will move in his or her individually best possible way to achieve the task. If the task is modified (e.g., "Come get this cookie"), the child will move differently. The child might awkwardly run instead of walk. He or she might drop down and crawl, if crawling is the best way to move quickly. If instead, the environment is changed, perhaps by the lawn being coated with ice, the best movement for the child to use to get to Point B will change again. Over time, the child changes, by growing stronger and by becoming better coordinated and more experienced with walking. Then the same task in the same environment will have a different outcome, because the individual has changed. Even later, the adolescent growth spurt dramatically changes the child's individual characteristics, seemingly overnight. Teenagers are clumsy because they have physically changed, and well-learned tasks are done awkwardly because the body's contribution to the system's interaction in finding a solution to the task is dramatically different.

In the classroom, changes of environmental demands (e.g., placement and number of desks or computers, grouping of students) or task demands (e.g., writing vs. speaking, personal opinion vs. referenced information, allowed resources) all affect the type of work (outcome) that a student will produce. While such changes often lead to obvious outcomes that seem to just naturally happen, a question to ask is whether the dynamic systems model could be used to create change in a system on purpose, in order to move a system to better levels of development and efficiency.

In education, dynamic systems theory has been used to propose rethinking of curriculum (Ennis, 1992) and school organization (Coppieters, 2005). In the area of motor development, Newell (1986) and Kelso (1995) both proposed that changing characteristics of a system can influence natural motor development. Movement is not merely a result of physical and/or cognitive development. Changes of the environment or the task create chaos that will lead the motor system to more functional motor performances. Whinnery and Whinnery (2007) used a dynamic systems model to critique motor development programs for children. Glazier and Davids (2003) used Newell's model to suggest changes in approaches to teaching the golf swing. Scholz (1990) used dynamic systems models to address physical therapy programs. Experiences change the learners and what each will bring to future learning situations, in the form of intrinsic dynamics (Kelso, 1995).

APPLICATIONS

In learning situations, teachers are in the unique position of being able to control many aspects of the learning situation. While impacting the characteristics of the learner may be a long-term project, teachers can plan and use learning experiences that can influence these characteristics. The teacher can influence the environment by changing the physical arrangement of the environment, the grouping of learners, or the available spaces within which the learners work. Of course, the tasks presented to learners are almost totally within the teacher's control. A teacher's decisions regarding selection of task goals, available equipment, and limits to student responses can greatly affect learners' responses in a learning situation. Figure 2 illustrates potential environmental and task manipulations for a library skill and a motor skill. Not all manipulations occur at one time, however. They can be used individually to sequentially move students to preferred outcomes.

FIGURE 2 — EFFECTS OF ENVIRONMENTAL AND TASK MANIPULATIONS

1. More than one way exists to complete a given task or process.	
Library/Research Numerous tools, both free and subscription, exist for locating and accessing books, periodicals, and other forms of information.	**Motor Learning** When shooting a basketball, the options of where to place the hands and feet and how to sequence and time movements are innumerable.
2. While there may be many ways to complete a given task, certain ways are more preferable than others.	
Library/Research Free online search tools will turn up periodical literature, but subscription databases will turn up a wider list of results.	**Motor Learning** Shooting a basketball can be done from below the waist, at the side of or above the head, or any location along the body, and can be done either one- or two-handed. In game-like situations, the likelihood of making a basket is higher if the ball is released from above the shoulders, to avoid a defender.
3. Instructors can develop environments that, while offering different choices for completion, invoke a preferred choice as being most efficient or accurate.	
Library Research Many individual catalogs and consortial options (Open WorldCat) exist for students to locate books. Finding books in a specific library is most efficient in the library catalog.	**Motor Learning** Varying heights of baskets, sizes and weights of basketballs, and shooting distances will affect learners' techniques and can facilitate or hinder above-shoulder releases. Adding passive and active defenders will also affect technique.
4. Incorrect choices, mistakes, dead ends, or even failure can be valuable to student learning when paired with successful choices.	
In this model, student learning is derived from self-reflection and evaluation of those choices that work better than others. Instruction is based on providing an initial task or changing a subsequent task that invokes preferred choices (and allows students to choose other options).	

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THE ECOLOGICAL TASK ANALYSIS MODEL

Davis and his colleagues (Davis & Burton, 1991; Balen & Davis, 1993) used Newell's 1986 Model of Constraints to develop a curricular approach, the Ecological Task Analysis (ETA) model, for the teaching and assessment of motor skills, with an additional focus on use of this model in Adapted Physical Education settings. Ecological Task Analysis is a generic model, however, and provides a concept that teachers could use to teach any content. Of significance in the ETA model are two views: that a task is a function that meets a specific intention, and that any intention can be met in several different combinations of specific performances. Davis and Burton did not accept the more common use of "task analysis"—analysis of the demands of a skill to determine the specific set of "correct" techniques to be learned to meet a skill's demands—or the use of these analyses to develop teacher-centered learning tasks to teach the desired skills. They proposed that the learning environment and task demands can be analyzed, manipulated, and used to facilitate students' response choices. Within this process, learners discover and develop their own best solutions for meeting the intentions of the task that they are addressing. Teaching then becomes an analysis of students' initial responses to the task and facilitation of each student's development of his or her own best solution to the challenges presented. In this model, instruction is not used as a way to demonstrate preferred performances or to identify and correct incorrect performances while coaching learners toward the teacher's preconceived solutions. Instruction is based on a teacher's observations of learners' responses, and is directed toward these outcomes. Demonstration and direct instruction are initially withheld, to allow students to explore the available choices and to develop individual solutions. Davis and Burton saw early instruction in a lesson as limiting learners' responses to a focus on replication. Early challenges allow a focus on creation of a student's best response. Later, instruction is used to respond to students' solutions. After responses have developed, direct instruction is used to expand and refine these responses.

The ETA model was developed for the assessment and teaching of movement tasks, but it is an accessible model that a teacher could apply to other curricular areas. Teachers' expertise in various content areas can enable them to apply ETA concepts to cognitive, performance, and research areas. Using a teacher's expertise to initiate systematic changes in the classroom environment and the learning tasks prescribed enables more effective curricular and teaching change. Snavely (2004), Spence (2004), and Pelikan's (2004) descriptions of their work using problem-based learning as an approach to information literacy instruction echoed aspects of the ETA model (though not naming their practice as such). In these sessions, students were given scenarios that required some sort of research need (the task). Instructors provided a preselected set of manageable resources (the environment) for students in classroom practice, without providing instruction as to the steps to take or the order. Pelikan described the importance of nonintervention when students get stuck, to avoid stopping the exercise. Learners need the opportunity to work things out for themselves. After allowing students to struggle for some time, Pelikan used guided questions to help students focus on their research need before letting the class search again (modify the variables). All elements of the ETA model have been utilized.

Seel (1999) urged implementation of dramatic changes to a system in order to generate change of any significance. He argued that if too much system stability remained after a change had been introduced, permanent change could not occur. He also warned, however, that if too much randomness were present, self-organization would be less likely to occur. Small, systematic, persistent changes seem most reasonable.

CLASSROOM APPLICATION

A teacher can manipulate constraints within any classroom activity to lead to learner-centered

solutions to challenges—solutions that would be individual best solutions emerging from the dynamic interaction of each student's three component factors. As a teacher designs and implements a lesson or curriculum following the Ecological Task Analysis model, Davis and Burton presented four specific steps to ensure that the benefits of the model can be realized:

1) Establish the task goal, to oneself as the teacher and to the learners.

2) Provide choices of environment, tasks, procedures, and equipment that will ensure that learner responses are not narrowly limited.

3) Manipulate the environment, or the task or parts of the task, across varied constraints, in response to learners' initial responses.

4) Provide direct instruction, for simplification or challenge to the learners.

Davis and Burton placed these steps along a continuum; however, it need not be a strictly linear model. Figure 3 shows a modified, recursive version of this model. Steps 3 and 4 may be invoked time and time again during the course of a lesson, new choices can be introduced, and new task goals can be established, all to further develop and refine students' results.

Without being too prescriptive in describing techniques that will "work" (a "cookbook" procedure that is not consistent with the Ecological Task Analysis approach and should be avoided), some suggested uses of this model within the library instruction curriculum are provided here. Some of these modifications have been attempted in "one-shot" library instruction sessions for introductory-level writing classes, and others in a term-long academic setting—60 to 90 students (mostly first- and second-year university students) in a university-required fitness/wellness class. In both situations, a library research component is part of the course.

Example 1*: Focus on information sources and tools (may be done in a single 1-hour session or over several short 20-minute class sessions).*

Task 1: *Research without constraints*

Students are provided a current event (taken from Wikipedia's current events section) or a pertinent course content topic or issue and asked to find several sources of information they deem suitable for a research assignment.

FIGURE 3 — ECOLOGICAL TASK ANALYSIS MODEL—MODIFIED FROM DAVIS AND BURTON

Establish Task Goal • Structure the environment • Give info about the task • DO NOT demonstrate	**Provide Choices** • One size does not fit all • Have selection of skills, movements, and equipment available • Allow safe student decisions
Modify the Variables • Restructure the environment • For the group and for the individuals who are ready	**Provide Instruction** • Only **AFTER** first three steps • Instruct about skills students have selected • Instruct about teacher-preferred skills

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Students generally choose free online search tools. Some students who have received previous library instruction may choose subscription databases. Their work may be used as a point of discussion.

…leads to…

Discussion regarding the suitability of information sources within an academic context.

Task 2: *Research with some constraints (changing the task)*

Students are asked to research again, this time looking only for those sources of information with complete bibliographic information.

…leads to…

Discussion about print/online vs. online-only sources of information, and the desirability of using materials that have some sort of basis in print publication (or that may have a permanent archive).

Task 3: *Research with more constraints (changing the task)*

Students are asked to research again, this time looking only for those sources of information that contain complete bibliographic information, based on print materials (generally newspapers and newsmagazines). Students might experience some difficulty in finding print-based sources of information for very current events. This may be used as a discussion point about the nature of search engines and what sorts of items are typically indexed.

…leads to…

Discussion of where students might find such information in an online environment.

Task 4: *Research with more constraints (changing the environment)*

Students are asked to research again (the same task), but this time, they are required to use several different library subscription databases—a popular periodicals database, a newspaper database, and the library catalog—as well as Google News. Finding just one solution is not good enough, however. Several routes to a solution must be explored. Even during this task, demonstration or instruction is not necessary, save to explain to students where on the library Web site they might find links to the databases. Instruction regarding the nature of the databases can occur later.

…leads to…

Discussion of applicability of various library resources as well as advantages and disadvantages of library subscription databases vs. free online services.

***Example 2**: Focus on information-seeking skills (may be done in a single hour-long session)*

Task 1: *Research with constrained choices*

Students are asked to search for a topic within a given tool—the library catalog or a subscription database—and are required to do the following searches:

- Keyword-only search
- Phrase search
- Sentence search
- Boolean search (keywords joined by Boolean operators)

This task may be further constrained. Instead of just two keywords joined by "and," a searcher might specify more keywords joined by "and" within a search.

…leads to…

Discussion regarding what types of searches students found to be most effective, in regard to the number and the accuracy of their results, in meeting the demands of their search.

Task 2: *Research with constrained choices (same task, different environment)*

Students are asked to research again, this time using different terminology derived from their earlier results (titles,

authors, subject headings, tables of contents, abstracts). Students are required to make use of the same choices as in Task 1.

…leads to…

Discussion about choices in regards to language used in searching for information, and where such language might be derived.

Task 3: *Research with constrained choices (same task, different environment)*

Students are asked to research again, this time within a different library tool (or a selection of tools). They are required to use the terms they found most effective in Tasks 1 and 2, and the same search choices from Task 1. Instruction during this task might be provided in support as students use different database interfaces.

…leads to…

Discussion of student results from their searching. Some students will discover that the same search techniques that were successful with one database were not successful with another, leading to discussion about database interfaces and scope.

In both examples and all tasks, direct instruction is withheld. Instruction may be provided to support students as they go through their various tasks. The tasks are progressive, with the manipulations leading students to more advanced uses of research resources. Learning outcomes are derived from student exploration, discovery and discussion.

DISCUSSION

This approach offers a number of advantages to the instructor willing to experiment with student learning in the classroom.

1. Students are immediately engaged. By withholding lecture and instruction, the instructor can focus students on their task from the beginning of the lesson.
2. Standards can be emphasized throughout. By placing constraints upon students as they go through their tasks, the instructor may ensure that students come up with only those types of information sources that fit within a specific academic context.
3. Choices may be required to ensure that students are exposed to a wide range of library tools and process skills. (The instructor's role during class activities is not only to provide support, but to enforce that students experience all required choices.)
4. This model accommodates students with a wide range of experience and knowledge. If the instructor has a class with students who are new to the library as well as experienced students, this approach allows experienced students to model behaviors to others (and relieves them of the burden of listening to the same lecture they have already received in the library). The instructor may then provide more support to those students without experience with library tools. Finally, if an instructor has a class experienced with library tools, the task may be modified so that students must make more advanced use of the tools.
5. This model can more closely follow the nature of real academic research (as the instructor can) by modifying tasks again and again, making the students' searching a recursive activity, following up on language and issues derived from the literature, and looking up bibliographic references.
6. It is presumed that retention is greater, since students learn from their own experiences and discoveries.

The authors must acknowledge, however, that there are inherent disadvantages in using this approach that all instructors must weigh before attempting it.

1. The approach generally takes more time to cover material than does a single lecture or demonstration (although this

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can be negated somewhat by withholding instruction until later; one might find that instruction or demonstration is wholly unnecessary).

2. The instructor must be ready to let students take some control over the learning outcomes. This model works because instructors can generally anticipate what sorts of behaviors or outcomes will be invoked from a given task. Nevertheless, students will often come up with unanticipated responses to a task. These responses, however, are often valuable as another point of discussion.
3. If instruction occurs over several class sessions, the process requires that the librarian become more than just a guest lecturer in the course. The distinction between expertise in different content areas within the course becomes blurred. This fosters pedagogical collaboration (a positive), but requires both content and search process collaboration that is different and potentially threatening or confusing for faculty and students.

Future Directions

The efficacy of this model for IL outcomes can only be reported anecdotally at this time. Initial questions that have been addressed by the authors have regarded efficiency of scheduling class presentations between faculty and librarians, coordination of IL content with course academic content, and scheduling of evaluation of students' work. Trends in students' work suggested positive changes in the quality and authenticity of the resources students have found for their assignments. Systematic evaluation of the quality of students' resources needs to be done to more precisely determine the effectiveness of the curriculum. A curricular question that needs to be addressed is to determine the extent to which any effectiveness of this approach is dependent upon the librarian's presence in the course. Can IL content be so integrated into a course's content that it becomes seamlessly integrated into the content of the course, with the teaching done by the academic faculty, or must guest lectures by librarians be a scheduled component of every course? Academic and library faculty must work out these logistical issues, but if the effectiveness of the curriculum is affected by the librarian's presence, this will necessitate specific levels of faculty/librarian collaboration.

Conclusion

In this paper, the authors have explored ways to change an individual's teaching. This has not, however, been an attempt to simply provide new tips, to be taken and tried out in the next class taught. While the Ecological Task Analysis approach looks at a different way to organize the teaching environment and learning tasks in order that higher levels of learning may occur, adoption and effective use of this model is contingent upon the instructor's acceptance of a particular philosophy of education—a philosophy that embraces the idea that true learning is about the process that learners go through on their way toward gaining and using information. If one believes that the answers are known, and that teaching is only the provision of these facts to students, using ETA is not necessary, nor is it advisable. To effectively use this model, a teacher must accept that there are many answers to any learning task and that there are different paths that could be followed or designed to ultimately reach more effective solutions. A teacher must also accept that individual students, within the obvious constraints established by the environment, the task, and within themselves, develop different solutions to problems. Having accepted this philosophy, a teacher may find that a dynamic systems approach can provide a sound model for implementing a teaching approach that meshes with this philosophy.

The first task for a teacher is to address the following questions:

> Can I influence the characteristics of the learner?
>
> > *Yes, over time, by the experiences that I provide.*

Can I change (structure) the environment?

Of course. Within very wide limits, I can select and arrange spaces and movements within the environment in many possible and varied ways.

Can I change the learning tasks?

Of course. An obvious role of a teacher is to decide, "What are we going to do today?" As a teacher, I have a lot of latitude regarding tasks and activities in my classroom and the grouping of students.

More importantly:

Can I allow and embrace students' engagement in the development of their responses to challenges?

While learner-centered teaching is a pedagogically sound approach, it is not what most teachers have experienced, and requires a dramatically different approach to teaching.

Most importantly:

Do I accept that there is more than one possible solution to any learning task that I am presenting to learners?

The answer to this question is crucial in determining the success that a teacher will have using a dynamic systems approach.

If the answers provided here seem reasonable to the reader, dynamic systems models are ready to help provide some guidance to this teacher as s/he moves toward more effective teaching.

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