Courses as Seeds: Expectations and Realities

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Abstract

In our long-term efforts to support collaborative learning, we are exploring how to supplement community-based learning theories with innovative collaborative technologies. Inspired by a process model that underlies the evolutionary and decentralized development of open systems, we reconceptualize courses as *seeds* rather than as finished products. This paper outlines the conceptual framework underlying the courses-as-seeds model and contrasts it with traditional educational models in which courses are seen as finished products. Characteristics of course information environments (CIEs) as supporting technology are then presented, along with a set of initial expectations that provide criteria for assessing applications of the model. Next, an application of the courses-as-seeds model in a university course is reported and analyzed with respect to the expectations.

We found that the primary challenges of applying the courses-as-seeds model were cultural in nature and more difficult than we anticipated. The paper presents these findings in more detail, and closes with suggestions for future refinement of the approach.

Keywords

Courses as seeds, seeding, evolutionary growth, reseeding model (SER), course information environments (CIE), DynaSites, educational models, cultural change, collaborative knowledge construction

Introduction

One of the most impoverished paradigms of education is a setting in which “a single, all-knowing teacher tells or shows presumably unknowing learners something they presumably know nothing about” [Bruner, 1996]. Despite the fact that significant efforts are under way to change the nature of school discourse to make it more of a collective inquiry [Scardamalia & Bereiter, 1994], this traditional model of education is still widely practiced in our educational institutions, leading critics such as Illich [Illich, 1971] to claim that our schools and universities are the "reproductive organs of a consumer society" and that "people who are hooked on teaching are conditioned to be customers for everything else."

The premise of this paper is that the traditional paradigm of education is not appropriate for understanding and learning to resolve the types of open-ended and multidisciplinary problems that are most pressing to our society. These problems, which typically involve a combination of social and technological issues, require a different paradigm of education and learning skills, including self-directed learning, active collaboration, and consideration of multiple perspectives. Problems of this nature do not have “right” answers, and the knowledge to understand and resolve them is changing rapidly, thus requiring an ongoing and evolutionary approach to learning.

As an alternative to the traditional educational paradigm, we envision courses as communities of learning in which participants shift among the roles of learner, designer, and active contributor [Rogoff et al., 1998]. The predominant mode of learning is peer-to-peer, and the teacher acts as a "guide on the side" rather than as a "sage on the stage." Courses are reconceptualized as seeds that are jointly evolved by all participants rather than as finished products delivered by teachers [Fischer, 1997]. Inspired by new models made possible by collaborative technologies, we have developed an educational model that we call *courses as seeds.*

Introducing a new educational model involves *cultural change* by all participants. Regardless of how well classroom activities are designed, or how sophisticated the supporting technology, these elements will not by themselves change the culture of education [Bruner, 1996]. Cultural change requires that participants critically reflect upon and possibly change their behaviors, goals, values, and attitudes toward education. Despite a growing body of research on collaborative learning (and computer support for collaborative

learning) [Koschmann, 1996], researchers have focused more on the role of collaborative learning in expanding students' learning experiences than on the cultural change needed to enable collaborative learning to take place in educational settings.

This paper presents and discusses students' responses to the attempt to implement the courses-as-seeds model in a traditional university setting. It first presents the courses-as-seeds model and its underlying evolution-based framework. It then highlights the expectations regarding important aspects of students' participation (in the classroom and otherwise), classroom activities, and the use of technology essential to realize and sustain this new model. Finally, a case study is presented, and the realities of this experience are analyzed against the theoretically motivated expectations.

Courses as Seeds

Courses as seeds is an educational model that attempts to create a culture of collective inquiry that is situated in the context of the university courses and yet extends beyond the temporal boundaries of semester-based classes and traditional prefabricated class materials. The essential aspects of the model are that students take an active role in their own learning processes and that these learning processes are embedded in collaborative activities supported by innovative technologies.

The subject areas we want to investigate do not contain answers that can be found in textbooks or derived in a semester, but instead are complex, vague and open-ended problems. Within our model, students are *designers* and *reflective practitioners* who must frame the problems they will investigate [Schön, 1983]. The knowledge to understand, frame, and solve design problems does not exist a priori, but is constructed and evolved by exploiting the power of the "symmetry of ignorance" [Rittel, 1984] and "breakdowns" [Winograd & Flores, 1986]. Central to the notion of design as a model of collaborative work and learning is the construction of a publicly accessible artifact [Bruner, 1996] that serves as both a reification of shared understanding and grounding for the creation of new understandings.

Collaborative technologies are providing new ways to conceptualize what such a shared artifact can be. In the past a physical artifact was separate from the discussions and decisions that helped shape it. Modern collaborative technologies allow these discussions and decisions to be captured and considered as part of the artifact. For example, hypertext technologies enable students to create artifacts that link and extend each other's contributions to express new understandings [dePaula, 1998]. The result of such knowledge building is an information space that can serve as the starting point for future students, who bring new perspectives and framings to the problem. It is this sense of ongoing, collaborative learning through design that we wish to support with the courses-as-seeds model.

Because it is impossible and even undesirable to precisely determine the direction and outcome of learning in the courses-as-seeds model, this learning must be viewed as an evolutionary process of "design without final goals" [Simon, 1996]. From this perspective, breakdowns in understanding do not cause embarrassment to instructors and frustration to students, but rather provide opportunities for learning and new directions for inquiry [Koschmann et al., 1998]. Accordingly, the courses-as-seeds model requires a mindset in which plans conceived at the beginning of the course do not determine the direction of learning, but instead provide a resource for interpreting unanticipated situations that arise during the course [Suchman, 1987].

The SER Model: An Evolution-Based Framework

As an alternative to the structuring role of the syllabus in traditional education, the courses-as-seeds model is structured by a framework for both planning and situated action within evolutionary learning processes, namely the seeding, evolutionary growth, reseeding (SER) model [Fischer, 1998b]. The "courses as seeds" name is derived from the SER model, which describes social and technical forces that drive long-term evolutionary design of complex systems (including artifacts and information spaces).

In the past, complex systems have been created through a very large effort by a relatively small group of people. The SER model describes an alternate approach in which complex systems are evolved through small contributions of (very) large, and often distributed, communities. We have explored the feasibility and usefulness of the SER model in the development of domain-oriented design environments, high-functionality applications, organizational memories, and open systems approaches. The evolution of these systems share common elements, which we now relate to the courses-as-seeds model.

Seeding. A *seed* is the initial state of a system that is intended to evolve. It is created by environment developers (in the case of computational systems) and by instructors (in the case of courses) to be as complete as possible. However any complex system is incomplete in principle due to the situatedness and tacit nature of knowledge as well as the constant change occurring in the environment in which the system is embedded [Suchman, 1987; Winograd & Flores, 1986]. A seed is therefore conceived as an open-ended system, and designed to evolve as it is used in the evolutionary growth phase.

Evolutionary Growth. The evolutionary growth phase is one of unplanned evolution as the seed is used by the members of a community to do work. During this phase, the seed plays two roles simultaneously: (1) it provides resources for work, and (2) it accumulates the products of work. In the courses-as-seeds model, evolutionary growth is driven by investigations and projects that look at a problem or issue from a new perspective, and then share this new knowledge with the course at large.

Reseeding. Reseeding is a deliberate effort to organize, formalize, and generalize knowledge created during the evolutionary growth phase [Shipman & McCall, 1994]. This knowledge has been created in the context of specific activities, without concern for or awareness of how it might relate to other activities that are concurrently proceeding. Reseeding processes are necessary to maintain a coherent system that can be extended in the next evolutionary growth phase. In the courses-as-seeds model, semester breaks provide a natural opportunity for instructors to reseed the course information space in preparation for the next course.

A New Culture of Education

The courses-as-seeds model represents a system of values, attitudes, and behaviors [Bodker & Pedersen, 1991] that is radically different from the traditional educational culture in which courses are conceived as finished products and students are viewed as consumers (see Table 1). It aims to create a culture based on a "designer mindset" [Fischer, 1999; Resnick, 1992], which emphasizes habits and tools that empower students to actively contribute to the design of their education (and eventually to the design of their lives and communities).

Table 1: Contrasting Courses as Seeds with Courses as Finished Products

Courses as finished products	Courses as seeds
Learners answer problems given to them by the instructor	Learners construct knowledge about topics that are personally meaningful
Learners interact mainly with the teacher and compete with other learners for grades	Learners are a community of practice that collaborate to build shared understanding
Learners are complete novices in the subject matter and make no contribution to other students	Course participants are knowledgeable in their own working environments and have much to offer
A course is given over a period of years, more or less in the same form	A course is considered as a seed that will evolve continuously in future courses
Learners are recipients of knowledge (the assumption is that the teacher/instructional designer has all the relevant knowledge)	Learners are not just passive recipients of knowledge, but active contributors (i.e., they actively co-design the class curriculum)

Course Information Environments

To create designer mindsets, we need to develop new media and new technologies that provide the opportunity and resources for social debate, discussion, and collaborative knowledge construction. In the culture of courses as finished products, the primary role of technology is to provide access to prefabricated learning materials. From the courses-as-seeds standpoint, the role of technology is to form and sustain active communities of learners [Rogoff et al., 1998] who contribute ideas from their own unique perspectives and connect them in new ways. From this perspective, mere *access* to existing information and knowledge (often seen as the major advance of new media) is a very limiting concept [PCAST, 1997] that at worst leads to "consumer" cultures [Fischer, 1998a].

Rather than using technology to "recreate education as it is," we have conceptualized educational technologies as *course information environments* (CIEs) that support the following activities:

1. *Learning discourse and social capital:* CIEs should not be passive repositories of information, but rather "living" information spaces [Terveen et al., 1995] through which members of a learning community can share ideas and build social relationships. To become an active member of a community means to build networks, and to learn about and contact other members of the community with similar interests, ideas, and goals; that is, it means to "learn to be."
2. *Building, referring, extending*: As opposed to merely delivering existing and prefabricated information to students, CIEs should provide the affordances for learners to extend the current state of knowledge, or an idea expressed by a peer, by contributing from their particular areas of expertise. The goal is not just an accumulation of information, but a collaborative construction of new knowledge.
3. *Formalizing, restructuring, reusing*: The "products" of each course contribute to a larger accumulation of information relevant to the course. The point is not that a CIE will hold answers to questions, but rather that it should contain resources that allow the next class to generate new ideas—to go beyond where they could have gone if they had started from scratch.

Because the CIE is persistent, it can serve as a source of assessment and reflection of course activities. Based on the courses-as-seeds model, the CIE for a given course should show the following characteristics:

- a growing and evolving information space, driven by course activities
- student-initiated contributions indicating personal interests and reflections
- rich interaction among all participants, as opposed to strictly between student and instructor
- knowledge building, including extensions to the original seed as well as to new ideas contributed by participants
- discussions and artifacts that can be incorporated into the seed for the next course in a reseeding process.

The "Technology-Arts-and-Media" course

As part of a new program, called the *Technology-Arts-and-Media (TAM*) [TAM, 2000] certificate program at the University of Colorado, the authors, together with Prof. Ernesto Arias, taught a course entitled *Designing the Information Society of the New Millennium* in the spring 2000 semester [Atlas, 2000; Fischer et al., 2000]. The major goal of this course was to allow students to explore new ways in which new media will impact learning, designing and collaboration in the information society of the new millennium. At the same time, the TAM course was an initial attempt to implement the courses-as-seeds model, providing a concrete context for analyzing, discussing, and reevaluating the expectations listed above.

Course Setting

The class, open to both graduate and undergraduates students, was announced as an interdisciplinary course in an attempt to attract participants from a wide range of backgrounds, interests, and experiences. The majority of the 30 students who enrolled were undergraduate (67%), male (70%), and from computer-science (86%).

The class met twice a week, and the activities were based on a series of assigned readings. Students were given questions for each reading, and asked to post their responses via the CIE website prior to the classes in which they would be discussed. Students were strongly encouraged to read and comment on each others' postings, although this was not mandated. Class discussions were based on the readings and responses, but were not necessarily restricted to the topic of the reading. Various guest presentations throughout the semester were embedded in the activities to provide students with different perspectives on the topics being discussed and allow them to touch base with experts. Two group projects during the semester allowed students to form groups and select topics. The first group project was book review and the second was a substantial research or system-building project.

Course Information Environment

The TAM CIE was intended to play a central role in course activities, to provide a means to access course information, and, more significantly for the goals of the course, to facilitate community formation and collaborative learning. The TAM CIE consisted of three web-based components: a course website, a

threaded discussion forum, and a community space that held and displayed information about the course participants.

The course website served as a repository of course materials and administrative information, including the syllabus, lecture slides, assignments, schedules and links. This site was conceived and implemented by the instructors before the course started. Even though the contents were updated frequently during the course, the website corresponds to the seeding phase of the SER model because it represents a consciously designed structure for the course.

The web discussion forum supported open communication among participants, who could post to existing topics, or start their own subjects, as desired. It was also used to support assignments as well as group projects. The technology employed for the forum was the DynaClass system, which is implemented within the DynaSites substrate [Ostwald, 2000].

The community space on the website, also hosted by DynaSites, supported course participants in creating their own *persona*. It consisted of a page containing information about the participants, including pictures, interests, a homepage URL, and whatever else they wished to share. Personas were intended to help participants establish an identity, and to find other class members with whom to collaborate, based on mutual interests or complementary experiences. Postings to the forum contained links to the author's persona to help readers associate a person with a posting. A link on each persona page retrieved all the postings made by that person in the forum, providing a portfolio view for each participant.

Realities - Assessment of the TAM course

As an experimental course, assessment was considered essential for students, who were being asked to participate in a new style of learning, as well as instructors, who were learning through its implementation. A variety of qualitative assessment methods were employed as intrinsic course activities, including public anonymous questionnaires and frequent discussions about the course, held within class and within the forum.

Responses to questionnaires indicate that students' reactions to the course were very strong and were bi-polar in nature. The two extremes are represented by the following two comments:

> *I will not ever take a course of this nature again in my undergraduate career…*
>
> *I rank this class in the top three that I've taken at CU … this is one of the first courses where I was treated as an adult, a fact which means more to me than I can describe.*

This section examines the roots of these reactions by analyzing the final state of the TAM CIE after a semester of evolutionary growth. It then discusses the mindsets and cultural forces that led to its final state and provide possibles new directions to overcome the difficulties faced during the class.

Analysis of the TAM CIE

At the end of the semester, the CIE forum contained 360 postings organized into 19 threads, of which 8 were devoted to reading assignments and 5 to group projects and questionnaires. Postings in response to reading assignments accounted for more than 75% of the total postings. Table 2 highlights differences between the discussion structures for spontaneous threads (i.e., initiated by students) and assignment-driven threads. These data show that assignment-driven participation took the form of very flat threads (meaning mainly responses to a single posting) consisting of long entries, and involved almost total participation from the class. By comparison, spontaneous threads were deeper (meaning there were responses to responses), with shorter individual postings, and limited participation.

Table 2: Participation on DynaClass Discussions

Comparison of spontaneous and assignment-driven threads in the CIE forum. Weighted average thread length is a common measure of the hierarchical thread structure, and provides an indication of the thread's "interactivity." A weighted average length less than 2 indicates a flat structure, in which all responses are to a single posting.

	Assignment-driven	Spontaneous
Weighted Average Thread Length	2.02	3.25
Average Message Size (in characters)	2940	538
Average Number of Responses	21.6	6

This evidence indicates that interaction within the CIE failed to realize the student-initiated participation that was expected. Activity in the forum was dominated by the reading assignments, to which students posted long responses but only extremely rarely commented on another student's response.

Data from the questionnaires showed that students viewed the forum as a means to submit homework assignments, but not as a means to interact with their peers, as illustrated by the following comments about the use of the CIE.

> *[DynaClass] is a very new and useful way of turning in assignments.*
>
> *The weakness in dynasites is that some people may see what others are writing for their responses and copy the answers.*
>
> *We are using it as a forum for submitting homework rather than a tool for "Collaborative Knowledge Construction".*

Evidence of a Culture Clash

The use of the CIE forum as a means to submit homework rather than a vehicle for peer-to-peer interactions that generated new ideas and relations among participants is a strong indication that the TAM course failed to break from the traditional educational culture.

The instructors intended to spur peer-to-peer interaction by assigning reading materials and requiring students to post their responses in the CIE. The instructors reasoned that because students' postings would be available to their peers, that interesting discussion based on these postings would follow. Instructors made the assumption that students would be intrinsically motivated to interact with their peers, and therefore did not make it an explicit part of the grading criteria.

Students, meanwhile, must deal with competing demands from other classes for their time and attention. These external demands may lead students to do only what they consider as necessary to get a good grade. The high participation rates and considerable length of assigned postings show that students were motivated to spend considerable time and effort fulfilling the explicit requirements for a good grade. They were not motivated, however, to spend the additional time required to read and comment on the responses of their peers.

In the end, the students received a mixed message. The graded assignment policy reinforced the traditional model the students were used to, whereas the content of the course and the rhetoric of the instructors implied a different model that assumed students would go beyond the minimum. Perhaps as a result of this mixed message, some students remained unconvinced of the value of self-directed, peer-to-peer learning. They continued to consider themselves as consumers of education, expecting the instructor to lecture predetermined and well-defined materials as in the traditional model. Their behavior was grounded in the following beliefs (illustrated by quotations):

- Learning is a one-way process in which students are strictly recipients:

  The main feeling that I get from this course is that we are heavily pressured for feedback.

- Problems have an answer and the teacher has to know the answer:

  Why should I pay fees if the teacher is not willing to provide me with the answer?

- Students were at best not interested, and at worst unwilling, to engage in peer-to-peer learning:

  Why should I learn from a peer when the faculty member knows the answer so much better?

In contrast, the course and the resulting CIE had many positive aspects. The course projects showed imagination and collaboration, and the final reports posted to the forum will be good examples for the next class to emulate and extend. The personas in the community space will preserve the presence of course members, and hopefully will enable interaction between former and current course participants and the establishment of a community that spans semester boundaries. The forum has also preserved some excellent student-initiated discussion of the courses-as-seeds philosophy and practice. We feel that this will also benefit future participants as they struggle to understand and participate in the new form of learning the courses-as-seeds model tries to realize.

Instructors experienced as much learning as students in this initial application of the courses-as-seeds model. We learned that the mere presence of collaboration technology is not enough to affect cultural change, and also of the importance of carefully designing course activities within the context of the traditional university structure. Students must see themselves as active members of a community that extends beyond classroom boundaries, and must realize the benefits of being part of this community. The courses-as-seeds model requires a great deal of extra effort from both instructors and students. We learned that extra time must be provided to support peer-to-peer learning as a first class activity. In the next offering of the TAM course, assignments will encourage shorter postings and incorporate the practice of commenting on the postings of others into the explicit grading policy. Instructors will spend less time grading lengthy assignment responses and more time facilitating and participating in the forum discussions.

We continue to learn as we struggle to incorporate very useful student feedback about the DynaClass and "Persona" technologies, and also to understand how to reseed the information space from the TAM course so it can best serve the next course offering.

Conclusions

New media and new technology provide us with new exciting possibilities to rethink teaching, learning, and courses at universities focused on these activities. Almost all serious educational reformers believe that new media and new technology on their own cannot transform universities to meet the demands of the future. Technology is only one part of the necessary cultural change. Cultural change implies that all stakeholders participating in the process of change have to reflect and change their behaviors, their objectives, and their values.

We have learned from this experience that students are likely to be strongly influenced by the values they have learned from their previous educational experiences, which are reinforced by the current university culture. Attempts to instill new values cannot be conceived in isolation but instead must take this cultural clash very seriously.

In the days where the future of universities are seen by many to lie in the virtual world, and where education is often reduced to a commodity, we need to understand the core competencies of residential, research-based universities. Courses as seeds is a promising model to evolve and enrich courses by allowing students to act as active contributors and not just as passive consumers. Cultural change beyond the adoption of new technologies is required in our current system in which students have been taught to take on the role of consumers of education. This change will require innovation and risk taking by faculty members. We will use the findings documented in this paper to further improve the courses-as-seeds model.

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References

Atlas (2000) *Atlas: Alliance for Technology Learning and Society*, at http://www.Colorado.EDU/ATLAS/.

Bodker, K. & Pedersen, J. (1991) "Workplace Cultures: Looking at Artifacts, Symbols and Practices." In J. Greenbaum & M. Kyng (Eds.), *There's No Place Like Home: Continuing Design in Use Design at Work: Cooperative Design of Computer Systems*, Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 121-136.

Bruner, J. (1996) *The Culture of Education*, Harvard University Press, Cambridge, MA.

dePaula, R. (1998) *Computer Support for Collaborative Learning: Understanding Practices and Technology Adoption*, unpublished Masters Thesis, Interdisciplinary Telecommunication Program, University of Colorado at Boulder, Boulder, CO.

Fischer, G. (1997) "Evolution of Complex Systems by Supporting Collaborating Communities of Practice." In *International Conference on Computers in Education, Kuching, Malaysia*, Association for the Advancement of Computing in Education (AACE), pp. 9-17.

Fischer, G. (1998a) "Beyond 'Couch Potatoes': From Consumers to Designers." In IEEE (Ed.), *1998 Asia-Pacific Computer and Human Interaction, APCHI'98*, IEEE Computer Society, pp. 2-9.

Fischer, G. (1998b) "Seeding, Evolutionary Growth and Reseeding: Constructing, Capturing and Evolving Knowledge in Domain-Oriented Design Environments," *Automated Software Engineering*, 5(4), pp. 447-464.

Fischer, G. (1999) "Lifelong Learning: Changing Mindsets." In G. Cumming, T. Okamoto, & L. Gomez (Eds.), *7th International Conference on Computers in Education on "New Human Abilities for the Networked Society" (ICCE'99, Chiba, Japan)*, IOS Press, Omaha, pp. 21-30.

Fischer, G., Arias, E., & dePaula, R. (2000) *Designing the Information Society of the New Millennium - Course Website*, at http://www.cs.colorado.edu/~l3d/courses/atlas-2000/.

Illich, I. (1971) *Deschooling Society*, Harper and Row, New York.

Koschmann, T., Kuuti, K., & Hichman, L. (1998) "The Concept of Breakdown in Heidegger, Leont'ev, and Dewey and Its Implications for Education," *Mind, Culture, and Activity*, 5(1), pp. 25-41.

Koschmann, T. D. (Ed.) (1996) *CSCL: Theory and Practice of an Emerging Paradigm*, Lawrence Erlbaum Associates, Mahwah, NJ.

Ostwald, J. (2000) *DynaSites*, at http://www.cs.colorado.edu/~ostwald/dynasites.html.

PCAST (1997) *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*, at http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.html.

Resnick, M. (1992) *Beyond the Centralized Mindset: Explorations in Massively-Parallel Microworld*, Ph.D. Dissertation, Department of Computer Science, Massachusetts Institute of Technology, Cambridge, MA.

Rittel, H. (1984) "Second-Generation Design Methods." In N. Cross (Ed.), *Developments in Design Methodology*, John Wiley & Sons, New York, pp. 317-327.

Rogoff, B., Matsuov, E., & White, C. (1998) "Models of Teaching and Learning: Participation in a Community of Learners." In D. R. Olsen & N. Torrance (Eds.), *The Handbook of Education and Human Development — New Models of Learning, Teaching and Schooling*, Blackwell, Oxford, pp. 388-414.

Scardamalia, M. & Bereiter, C. (1994) "Computer Support for Knowledge-Building Communities," *Journal of the Learning Sciences*, 3(3), pp. 265-283.

Schön, D. A. (1983) *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York.

Shipman, F. & McCall, R. (1994) "Supporting Knowledge-Base Evolution with Incremental Formalization." In *Human Factors in Computing Systems, INTERCHI'94 Conference Proceedings*, ACM, New York, pp. 285-291.

Simon, H. A. (1996) *The Sciences of the Artificial* (third ed.), The MIT Press, Cambridge, MA.

Suchman, L. A. (1987) *Plans and Situated Actions*, Cambridge University Press, Cambridge, UK.

TAM (2000) *Technology Arts Certification Program*, at http://www.Colorado.EDU/ATLAS/certific.html.

Terveen, L. G., Selfridge, P. G., & Long, M. D. (1995) "Living Design Memory: Framework, Implementation, Lessons Learned," *Human-Computer Interaction*, 10(1), pp. 1-37.

Winograd, T. & Flores, F. (1986) *Understanding Computers and Cognition: A New Foundation for Design*, Ablex Publishing Corporation, Norwood, NJ.