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AUTHOR	Ashley, Richard D.
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ABSTRACT

This report summarizes a project in which a number of new approaches were taken to improve learning in undergraduate basic music instruction for music majors. The basic viewpoint proposed was that music activities can be seen as skilled problem solving in the areas of aural analysis, visual analysis, and understanding of compositional processes. Computer software was developed for each of these areas using visual representations of musical scores, compositional programs controlling MIDI synthesizers, and CD (compact disc) players controlled by the computer for analytical listening. A number of tables and graphs containing analysis and information from the research study are included. (Author/DB)

Final Report
to
Fund for the Improvement
of Post-Secondary Education

"Redesigning the Content and Sequence of Instruction in Music Theory"

Grantee Organization:

Northwestern University
School of Music
711 Elgin Road
Evanston, Illinois 60208-1200

Grant No:

G008642203-88

Project dates:

Starting date: September 1, 1986
Ending date: December 31, 1989
Number of months: 40

Project Director:

Richard D. Ashley
Assistant Professor of Music
School of Music
711 Elgin Road
Evanston, Illinois 60208-1200
Telephone: (708) 491-5431

FIPSE Program Officers:

Bill Thompson
David Holmes

Grant Award:		
	Year 1	$ 39,426
	Year 2	$ 45,338
	Year 3	$ 44,736
	Total	$129,500

Summary

A number of new approaches were taken to improve learning in undergraduate basic music instruction for music majors. The basic viewpoint proposed is that musical activities can be seen as skilled problem solving in the areas of aural analysis, visual analysis, and understanding of compositional processes. Software running on Macintosh computers was developed for each of these areas, using visual representations of musical scores, compositional programs controlling MIDI synthesizers, and CD players controlled by the computer for analytic listening.

Project Director:

Richard D. Ashley
Assistant Professor of Music
School of Music
711 Elgin Road
Evanston, Illinois 60208-1200
Telephone: (708) 491-5431

Project reports:

- "Structure and strategy in analytic listening."
- "Eye training, analytic reading, and theory anxiety."
- "Music learning--compositional thinking."

Project software:

ScoreScan and Imager, for analytic reading of scores
BigEars, for analytic listening

Executive Summary

"Redesigning the Content and Sequence of Instruction in Music Theory"

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Northwestern University
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711 Elgin Road
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Grant No: G008642203-88

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Project Overview

Our project began in 1986 with a desire to develop a more realistic kind of basic instruction for undergraduate music majors. We saw the nature of musicianship as skilled, real-time problem solving within the multidimensional contexts posed by these pieces of music, and the challenge of developing instructional environments and processes for young musicians as that of encouraging the development of these problem-solving skills. The computer was seen as an integral element in the development of appropriate instructional environments. Over the course of three years, we developed materials for the development of these problem-solving skills in the areas of understanding of music-compositional processes, analytic reading of musical scores, and analytic listening to music. Some of these materials are designed for use in the classroom; others run on Macintosh computers, which should be equipped with MIDI-controlled synthesizers and CD-ROM players capable of playing audio CDs.

Purpose

Typically, music theory classes work "bottom-up" in developing concepts and skills, working from the level of single notes or pairs of notes to chords composed of three notes, joining these chords together in sequences, and finally working up to "real" musical compositions. Our contention was that musical abilities develop best *in vivo* as musicians come into contact with the rich and challenging environments naturally posed by pieces of music. Dealing with pieces of music engages a student in a number of ways simultaneously: in the cognitive domain, the student is thinking about the symbolic representation of musical elements and their interactions; in the aural domain, he is thinking about the actual sounding elements of the music; in the visual domain, he is thinking about the printed version of the score and interpreting the wide array of symbols contained therein. The challenge of developing instructional environments and processes for young musicians can then be understood as that of encouraging the development of real-time musical problem-solving skills. The computer was important to our thinking in that it provided the potential for developing multi-media, real-time instructional environments where the student could "switch viewpoints" easily between aural, visual, and compositional modes of action, increasing the potential for interrelating these different aspects of a composition.

We developed tools and techniques for dealing with each of these areas, but were unable to integrate them into a single large learning environment. One way of expressing our use of the computer is that it went from being viewed as a primary "strategic weapon," on which all of our efforts would be based, to a "tactical" weapon, with the computer being used for specific, targeted, high-yield applications. It also became clear that one need in our work was to have not just an integrated, encapsulated curriculum which would require wholesale adoption by other schools, but a more flexible, tools-oriented approach.

Background and Origins

Northwestern was an ideal place to undertake this project for four main reasons. First, we have had a literature-oriented basic musicianship sequence for about 15 years, lending support to the idea of working with whole pieces of music. Second, Northwestern has a major strength in the area of computer music, giving us access to sufficient resources for the development of significant computer programs. Third, Northwestern has a high level of faculty involvement in teaching basic courses, so that the faculty involved with the grant could try out their ideas directly. Finally, Northwestern has a history of innovation in music curriculum, having had a FIPSE grant in this area in the late 1970s.

Five full-time faculty ended up participating in the grant to some degree, totalling 3 faculty FTE's over the course of three years. In addition, four graduate student programmers were engaged over three years, for a total of some 10-12 man-months. Equipment and facilities support came from a variety of sources. About $40,000 in research funds given to two of the faculty at the time they joined Northwestern were used to provide software development platforms; an additional $4,000 was given by the School of Music to allow a campus-wide computer lab to be partially outfitted for music instruction. Since this time, and in great part due to the success of two of our software efforts, an additional $59,000 in grant monies has come to the School for instructional computing, from the Kemper and Wurlitzer Foundations and private donors. Thus, in addition to the $129,500 from FIPSE, at least $103,000 has been applied from other sources.

Project Description

Our efforts were mainly carried out in freshman Musicianship and freshman Aural Skills during the school years 1986-89. The major emphases were on four main types of learning activities: memorization of compositions, analytic listening, procedural modelling of musical structures, and analytic reading of musical scores. Each of these involved some pencil-and-paper or classwork as well as computer-based learning tasks; each was under the primary guidance of one faculty member, according to his interest and expertise. In addition, each was chosen to emphasize some aspect of understanding a musical composition which could then be integrated with other aspects to form a wholistic view of the work. Three of the projects (procedural modelling, analytic listening, and analytic score reading) involved writing new software for the Macintosh. Each of these projects produced a software system which has been used in classes for at least one quarter so far.

Project Results

The analytic listening and score-reading projects have become standard parts of Northwestern's curriculum. Actual data (of very different types) are available for these projects; in both cases, significant degrees of skill improvement are indicated. Interest in the analytic listening and score analysis projects has come from an increasingly large number of institutions beyond Northwestern. Schools interested in using the analytic listening software include Yale, the Eastman School of Music, the University of Michigan, Indiana University, the University of Illinois, and Arizona State University, among others; the score-analysis project has attracted attention from a like number of institutions. The LOGO programming and memorization projects have not been permanently adopted by our faculty. These activities proved to be very difficult for many students, and were deemed not worth the effort involved.

Our dissemination efforts are well-underway. Papers on our work have been given at the annual meetings of the Society for Music Theory, the College Music Society, the International Computer Music Conference, and the Music Teachers National Association, and have been published in the Proceedings of the ICMC. For the near future, our plans are to publish the analytic listening and score analysis materials as textbooks and as computer-assisted-instruction software, and to continue with developing full curricula around them.

Summary and Conclusions

At the outset, we overestimated the amount we would be able to accomplish in the grant, especially in terms of developing complete curricula around this multidimensional model of music learning. We shifted from our original all-encompassing model to one involving more focused tools, and have thus made our work more adaptable to other institutions. Although the tools for more successful multimedia applications are now much more mature than they were four years ago, our advice to others would be to develop well-targeted systems--especially those including an authoring system or other end-user capability--rather than attempt comprehensive solutions.

Final Report

Project Overview

Our project began in 1986 with a desire to develop a more realistic kind of basic instruction for undergraduate music majors. We saw the nature of musicianship as skilled, real-time problem solving within the multidimensional contexts posed by these pieces of music, and the challenge of developing instructional environments and processes for young musicians as that of encouraging the development of these problem-solving skills. The computer was seen as an integral element in the development of appropriate instructional environments. Over the course of three years, we developed materials for the development of these problem-solving skills in the areas of understanding of music-compositional processes, analytic reading of musical scores, and analytic listening to music. Some of these materials are designed for use in the classroom; others run on Macintosh computers, which should be equipped with MIDI-controlled synthesizers and CD-ROM players capable of playing audio CDs.

Purpose

Typically, music theory classes work "bottom-up" in developing concepts and skills, working from the level of single notes or pairs of notes to chords composed of three notes, joining these chords together in sequences, and finally working up to "real" musical compositions. Our contention was that musical abilities develop best *in vivo* as musicians come into contact with the rich and challenging environments naturally posed by pieces of music. Dealing with pieces of music engages a student in a number of ways simultaneously: in the cognitive domain, the student is thinking about the symbolic representation of musical elements and their interactions; in the aural domain, he is thinking about the actual sounding elements of the music; in the visual domain, he is thinking about the printed version of the score and interpreting the wide array of symbols contained therein. All of these things interrelate, and the student must often deal with them and their interrelations in real-time. Thus, musicianship can be seen as skilled, real-time problem solving within the multidimensional contexts posed by these pieces of music.

The challenge of developing instructional environments and processes for young musicians can then be understood as that of encouraging the development of these problem-solving skills. The computer was important to our thinking in that it provided the potential for developing multi-media, real-time instructional environments where the student could "switch viewpoints" easily between aural, visual, and compositional modes of action, increasing the potential for interrelating these different aspects of a composition.

We wished to give a complete curriculum based on a few core pieces of music, surrounded by related compositions. The core pieces would be examined from a large number of viewpoints, with the students returning to them over and over during the course of a year. This would be accomplished in large part by developing a computer music workstation which would allow the students to manipulate the music in a number of ways, including revoicing and reorchestrating the music, revising the score, and composing new works on the models of those they had already studied.

In fact,despite our progress and very real successes, this goal has proved to be still just beyond our reach. We developed tools and techniques for dealing with each of these areas, but were unable to integrate them into a single large learning environment. One way of expressing our use of the computer is that it went from being viewed as a primary "strategic weapon," on which all of our efforts would be based, to a "tactical" weapon, with the computer being used for specific, targeted, high-yield applications. It also became clear that one need in our work was to have not just an integrated, encapsulated curriculum which would require wholesale adoption by other schools, but a more flexible, tools-oriented approach.

A number of pitfalls appeared over the course of our project. First, we underestimated the amount of release time that would be needed to realistically achieve our goals. At the time of the grant, typical faculty loads in the School of Music at Northwestern were 8 courses per year (on the quarter system). After applying 2 courses release time per year from the grant, our loads were still about at the level of many FIPSE grantees **before** their release time was applied. Second, we should have used more of our money for student help in the areas of programming and evaluation. Our real advances in instructional software came in the second year of the grant, when the principal investigator decided to "pile up" resources on one project--the analytic score-reading program--and see it make good headway, rather than distributing the resources more thinly and seeing nothing moving ahead very quickly. With more help in evaluation, our time could have been spent more effectively at the end of the grant and firmer results would be available--instead of working on some remaining issues of evaluation after the grant is over. Finally, we needed to think more realistically about the "personal" and political realities of instituting change in our curriculum. Some of the older faculty reacted badly to the "young Turks" taking a leading role in revising the curriculum, and the breadth of support that would have helped us all was somewhat lacking until one of the senior faculty (John Buccheri) became integrally involved in the work of the grant.

Background and Origins

Northwestern was an ideal place to undertake this project for four main reasons. First, we have had a literature-oriented basic musicianship sequence for about 15 years, lending support to the idea of working with whole pieces of music. Second, Northwestern has a major strength in the area of computer music, giving us access to sufficient resources for the development of significant computer programs. Third, Northwestern has a high level of faculty involvement in teaching basic courses, so that the faculty involved with the grant could try out their ideas directly. Finally, Northwestern has a history of innovation in music curriculum, having had a FIPSE grant in this area in the late 1970s.

Five full-time faculty ended up participating in the grant to some degree, totalling 3 faculty FTE's over the course of three years. In addition, four graduate student programmers were engaged over three years, for a total of some 10-12 man-months. Additional (and crucial) programming support came from one of the staff members of Northwestern's Academic Computing team, who wrote the low-level routines needed for the Macintosh to control CD-ROM players for the analytic listening project. Equipment and facilities support came from a variety of sources. About $40,000 in research funds given to two of the faculty at the time they joined Northwestern were used to provide software development platforms; an additional $4,000 was given by the School of Music to allow a campus-wide computer lab to be partially outfitted for music instruction. Since this time, and in great part due to the success of two of our software efforts, an additional $59,000 in grant monies has come to the School for instructional computing, from the Kemper and Wurlitzer Foundations and private donors. Thus, in addition to the $129,500 from FIPSE, at least $103,000 has been applied from other sources.

The major organizational issues with which we dealt had to do with faculty autonomy in the classroom--in particular, did innovations introduced in one class have to be adopted by other instructors? This was a difficult issue in a situation such as ours where there is no overall curricular "head" other than the Dean of the School.

Project Description

Northwestern has a rather complicated undergraduate music curriculum. Students take "Musicianship" and "Aural Skills" for two years. The first of these is a class which meets three times a week for "theory" (essentially harmonic, stylistic, and formal analysis) and twice a week for "history" (straightforward music history by style periods). The classes are more or less integrated along the lines of style periods, but the exact degree of coordination between history and theory is largely a matter of the individual instructor's inclinations. "Aural Skills" meets three times a week, once in a large (30-50 students) lecture environment with a faculty member teaching and twice a week with a TA in a drill session.

Our efforts were mainly carried out in freshman Musicianship and freshman Aural Skills during the school years 1986-89. The major emphases were on four main types of learning activities: memorization of compositions, procedural modelling of musical structures, analytic listening, and analytic reading of musical scores. Each of these involved some pencil-and-paper or classwork as well as computer-based learning tasks; each was under the primary guidance of one faculty member, according to his interest and expertise. In addition, each was chosen to emphasize some aspect of understanding a musical composition which could then be integrated with other aspects to form a wholistic view of the work. Three of the projects (procedural modelling, analytic listening, and analytic score reading) involved writing new software for the Macintosh. Each of these projects produced a software system which has been used in classes for at least one quarter so far.

The simplest way to proceed is to describe the individual projects one by one; let us take them in the order in which they are listed above.

Memorization of compositions was primarily undertaken by Gary Kendall in his Musicianship class. The materials used were a Gregorian chant, the Prelude #1 in C Major from Book I of the ***Well-Tempered Clavier*** of Bach, and *Eleanor Rigby*, a song by the Beatles. A number of approaches were taken to learning these compositions; foremost among them were learning through repeated listenings, where the students had to be able to transcribe the pieces from memory on tests, and creation of "arch-maps" showing the hierarchic-temporal structure of the compositions (these also had to be reproduced in detail from memory).

Procedural modelling of compositions was the project overseen by Gary Greenberg. In this approach, students analyze pieces of music in terms of such things as motivic construction and the deployment of these motives over the course of a work. After analyzing the pieces in this manner, the students attempt to model the processes at work in the compositions by writing computer programs, in the LOGO language, which would produce pieces of music resembling those which had been studied. The presuppositions of this approach are those common to all LOGO-based instruction: that programming serves as a powerful learning method whereby a student's knowledge of a problem or structure grows through modelling the phenomenon under consideration as a computer program. The increased sophistication of the program as it is developed mirrors the increased detail and sophisitcation of the learner's internal representation of the problem; the learner is constructing new knowledge for himself in a discovery-based, interactive learning environment.

These programs were written in Object LOGO (by Coral Software--not available at this time) on the Macintosh. This implementation of LOGO contained the necessary low-level routines to allow access to MIDI synthesizers, and the students' exercises were played on small synthesizers to allow for better-quality sound than the Macintosh itself can produce. Prof. Greenberg spent a major portion of his time on the grant developing tools for the students to use in writing their own programs. These tools included routines that would arpeggiated chords, allow motives to be repeated, sequenced, and transformed; and permit the imitative interplay of motives defined by the student. Pieces dealt with in this manner were of varied types; there was an emphasis on compositions by Bach (Prelude 1 from Book I of the ***WTC***, the C Major and a minor Two-part Inventions) but also on more modern works (the second variation from Webern's *Piano Variations* Op. 27). Students analyzed the pieces in class and for homework, then met in one of the campus-wide Macintosh Laboratories to do their programming.

In the area of *analytic reading of musical scores,* John Buccheri developed text materials and software to assist students in carrying out musical score-reading activities, where the score is treated as a set of visual cues. He addressed the particular problem of knowledge representation for effective analytic score-reading by making two assumptions about how theoretical information is marshalled to produce efficient analytical score readings: One, that recognition of some theoretical artifact, for instance an altered chord, involves a process of matching an internal representation with the symbols which have triggered it; and two, that therefore the best representation of that altered chord may be a mental picture of the chord which resembles as closely as possible what is actually seen in the score. It is widely accepted that information may be stored in memory in two ways; by means of depictive representations of the sort just mentioned, and by means of propositional representations which are language-like descriptions of the relations among objects. I have created a set of "imaging exercises" which deal with chord vocabulary and certain properties of tonality. These are offered as mental calisthenics which can be used as preparation for score analysis. The user chooses a specific key and performs all of the appropriate exercises in that key. Propositional representations are incorporated in each exercise along with conscious mental construction of notes on a staff.

Of the many possible aspects associated with real-time reading procedures, Prof. Buccheri has chosen to investigate the high-order analytical task of determining the tonal profile of a piece--the succession of tonicizations residing in music which uses conventional major and minor scales. The location of a tonicization is considered a reading problem. The evaluation of the tonicization, its strength or quality and its hierarchical position in the prevailing key, is considered an interpretive problem to be taken up after reading. The several steps of the reading procedure may be outlined briefly: the score is scanned for pitches inflected by accidentals; assumptions are made about the tonicizing potentials of the inflected pitches; several questions concerning the context of the inflected pitches are raised at this time. Finally, original assumptions are verified, discarded, or refined and tonicizations are assigned. Inflected pitches not contributing to a tonicization are considered embellishments of the prevailing tonic. In terms of this score scanning routine, becoming an expert analytic reader can be characterized as follows; the novice is learning to ask the right questions at the right time; the intermediate reader gets good results from posing the questions; the expert never raises the questions-- he simply reads and knows.

In this project, called ScoreScan, the student is taught to quickly find potentially salient cues and use these to discover the direction and structure of the piece. Thus, the student is seen as learning a set of *musical facts*, such as "the raised fourth scale degree in the key of D Major is G-Sharp," and *heuristics*, such as "in a major key, expect a composition to modulate to the dominant; use the presence of the raised fourth scale degree as a cue to determine when this occurs." The student may engage in a number of levels of musical analysis, ranging from the "tonal profile," where only the larger, structurally significant harmonic motions are considered, to the more detailed chordal or nonharmonic level.

Because of the need for the development of speed in these activities, the timed presentation possible at the computer music workstation is particularly important. The computer programs developed in this project are implemented in HyperCard. Imager contains a large number of "flash cards" for drill in imaging important musical facts; ScoreScan contains several hundred analyzed scores which can be used for practice in such activities as tonal profile analysis.

The final project was one dealing with students learning a piece's structure totally by ear--what musicians refer to as *analytic listening*. This project attacked the problems inherent in analytic listening by taking a multi-faceted approach to developing these skills. Students carried out a wide range of activities, each of which was designed to reinforce the others in helping develop the ability to listen critically and analytically. Some of these activities were carried out in class, on paper; others were exercises to be completed with the aid of a recording in our Music Library Listening Center; still others were carried out with a specially-designed computer system for analytic listening, which runs on the Macintosh controlling a CD-ROM player. This system is written in HyperTalk, and contains an authoring system allowing lessons to be produced using any commercially-available CD.

The student's task in analytic listening, broadly understood, is to find significant relationships between musical structures by ear rather than by using a score. The approach taken in this project is to treat analytic listening as a kind of open-ended problem-solving activity. The problem to be solved is that of arriving at a suitable "mental model" of a piece, containing some representation of its important structures, events, and relationships. This must be done while dealing with the perceptual onslaught of real-time music listening. The student has to be *efficient* and to *know what to listen for* in a piece of music while it is proceeding, or else he might miss important aspects of the composition; he must also have access to good *models* of musical structure and to good listening *strategies*. Pieces used for models were largely from the Baroque period, emphasizing short dance-forms (from Handel's ***Water Music***) and concerto genres (from Vivaldi's ***Four Seasons***).

The first kind of activity in which we have had students engage is *comparative listening.* In order to help the student put those pieces which are studied in depth into some broader context, then, a number of related pieces--for example, different sonata-allegro movements, sets of variations, or concerto grosso movements--are assigned for listening without score. A short paper may be assigned, in which the student is asked to generalize about the pieces he has heard (along the lines of "what makes a concerto grosso"). The stage is then set for more concentrated work on individual pieces, viewing a piece of music from multiple vantage points, focusing, on the one hand, on the piece's hierarchic organization, and on the other, on its internal network of motivic and thematic associations. This is analogous to a kind of deep learning with which all music students are already familiar--*learning by rehearsal*, where the music is attacked from all angles to be totally accessible for the performer or conductor.

The first of these activities involves describing the sequence of events in the work. In the lecture environment, we represent segments of the music through traditional means by having small snippets of score given to the student which he then places on a timeline by letters, in the manner of many motivic or formal analyses. On the computer, a different method can be used. The student's task is to reconstruct the piece of music by arranging "blocks" of music on a timeline, where they can be played in order when desired. To help overcome a nonhierarchic or "flat" view of relationships between elements of the work, a second activity deals with the ways in which hierarchic grouping operates in the work.The student takes some segmentation of the piece--either one provided at a low level by the teacher, or which he himself creates--and recombines those segments into ever-larger units. In the classroom, the student listens and draws the higher-level arches which include the lower-level ones; on the computer, the student makes "blocks" of music while listening, which then are recombined into higher-level units.

Other kinds of relationships--those obtaining between non-adjacent elements in the music--are also of great importance. One technique used was that of having the students make a visual graph or network of the concepts, important events and features, and relationships between these, in order to make these more concrete and more easily seen. The students can use their graphs to facilitate class discussion and also when writing about the music to which they has listened, as a means of organizing their thinking in a pre-outline stage.

Project Results

Each of the projects mentioned in the last section has been adopted to some degree or other as a permanent addition to the undergraduate curriculum with the exception of modelling music-structural processes through computer programming in LOGO. These activities proved to be very difficult for many students, and no other faculty member had interest enough in them to pick up the work after the faculty member most directly involved left the School of Music. Actual data (of very different types) are available for the analytic listening and score analysis projects; in both cases, significant degrees of skill improvement are indicated. The project dealing with memorization of compositions has an intermediate status; some of its outcomes have been institutionalized, but its usage is totally dependent on the faculty involved in teaching the classes (some are interested, others are not).

Our successes and failures reflect, in part, the nature of Northwestern's undergraduate music curriculum. Projects which were successful tended to be so because of the faculty member's deep personal committment to the classes in which those projects were being pursued, and to his persuasiveness in getting other faculty members to adopt some of his ideas and techniques. A faculty member who was largely responsible for a class and its content quarter after quarter (as is the case with Prof. Ashley and his aural skills classes) could work on a project with enough sustained effort that it could come to fruition (as has happened in the analytic listening project). In other classes, such as Musicianship, a primary element in the successful institutionalization of the projects was the degree to which the faculty member could interest others in his work and get them to "buy into" it (as has happened with Prof. Buccheri and the analytic score-reading project). In other cases, where the faculty member was not involved for very long or was not convincing enough the projects failed over a period of time to be integrated into the program as a whole.

Again, it is simplest to deal with results of the four projects individually, in the same order in which they were described above.

No systematic evaluation of the *memorization of pieces* project was conducted by Prof. Kendall; after the one quarter in which he taught Musicianship in this manner, little use has been made of these techniques, so no hard-and-fast data are available. Anecdotally, it was evident from student tests that the material was in fact learned well, but that the tasks themselves were not interesting to the students and that, from the points of view of both teachers and students, the amount of work necessary to learn and reproduce the pieces in this manner was too large for the kind of learning achieved.

The *procedural modelling of musical structures* project is one about which we have mixed feelings. Prof. Greenberg is no longer a member of the School of Music faculty, and so information regarding the actual outcomes of his projects is scanty. As far as can be determined, none of the study tools typically used for Logo projects were applied here (in particular, protocol analysis techniques), and the actual student evaluations for the classes in which these activities were conducted are also unavailable. The prevailing viewpoint is that, although we were, and are still, attracted by many of the ideas expressed in these projects, overall they were not successful. The students had to work very long hours on their projects (sometimes 30 to 50 hours per project) in the Macintosh laboratory, spending the majority of their time on programming difficulties rather than on the actual music. In addition, to the ears of most, the musical quality of the student projects was rather low; many seemed to feel that better results could have been obtained with pencil-and-paper composition, with less time involve On the positive side, it is evident from the anecdotal reports of teachers having these students in other classes that their ability to write about pieces of music was substantially better than our other freshmen, due to the large amount of time spent on writing essays about the pieces which had been studied.

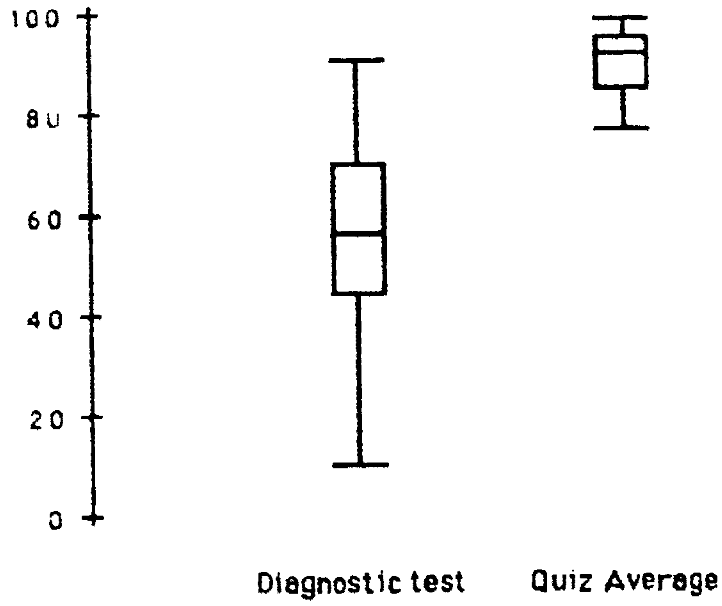
The other two projects have fared much better in terms of their outcomes, the analysis of their success, and their institutionalization. The *analytic reading* project has yielded materials which are consistently in use in the freshman year. It is difficulty to ferret out the impact these activities (the imagery exercises, the tonal profile exercises) have on the students apart from other, more traditional elements of the curriculum, such as Roman numeral analysis of harmonies, part-writing, and formal/stylistic analysis. However, we have good and firm data from another class which engages extensively in these activities, in order to understand the nature of the skills acquired and the level of skill improvement. Let us turn to this for a moment.

This class, "Score Reading Skills," is taught by Prof. Buccheri. It is composed of a mixture of undergraduates and graduate students representing a good cross-section of the School of Music. The emphasis in the class is on acquiring the necessary facts and heuristics for efficient analysis of scores. All diatonic and chromatic materials are covered which are normally found in tonal music, from the simplest of diatonic materials through easy modulations into music which combines several chromatic techniques simultaneously. Materials used in the class include scores of numerous works by Bach and Haydn, materials developed by Prof. Buccheri's concerning what aspects of a score are important to look at for a quick, high-yield understanding of the work, and exercises and computer programs which allow a student to practice to increase his skill level.

Upon entering the class, the students take a diagnostic examination which gives them examples of the tonal materials which will be covered in the class, in keyboard format and string quartet. Over the course of the quarter, a number of quizzes are given to gauge the students' progress in mastering the skills needed for efficient analytic reading of scores. The results given show the difference in skill level on entering the class as opposed to that achieved on the quizzes. One difficulty in the materials supplied by Dr. Buccheri is that the same test is not given as an exit test that was given as an entrance test, making exact comparisons of skill development impossible. Still, the evidence from the data shown below is that this is a remarkably successful technique (with the mean scores for the class increasing from ≈57% on the pretest to ≈90% on the quiz grades). These data reflect the experience and opinions of all teachers in our Musicianship sequence, who agree that the materials and methods Prof. Buccheri has developed are most useful.

The *analytic listening* project has taken a different tack in terms of evaluation. Skill in this area largely means being able to focus on the most significant elements of a work early on and then using these elements to create a meaningful internal "model" or description of the work. The effort to determine how students grew in their perception of a work over time used both quantitative measures (through testing) and qualitative measures (through protocol analysis, based on the transcripts of student activities taken in the course of using the BigEars system). Let us examine each of these in turn, using a group of 6 freshmen who used the BigEars system this year.

One way to judge the change in a listener's perceptions of an artwork is to look shifts in the data s/he collects from listening to the work from time to time. In the case of our students, we would expect that part of increased skill in aural musicianship would be the ability to move from the more "surface" features of the music--such as timbre, or instrumental tone-color--to more "structural" features of the work, such as form and harmony. In order to ascertain whether such a shift does in fact take place over the course of the freshman year, we had



Summary statistics for Diagnostic test
NumNumeric = 28
Mean = 57.250
Standard Deviation = 18.901

Summary statistics for Quiz Average
NumNumeric = 28
Mean = 89.571
Standard Deviation = 6.6857

t-Tests
pooled estimate of σ^2

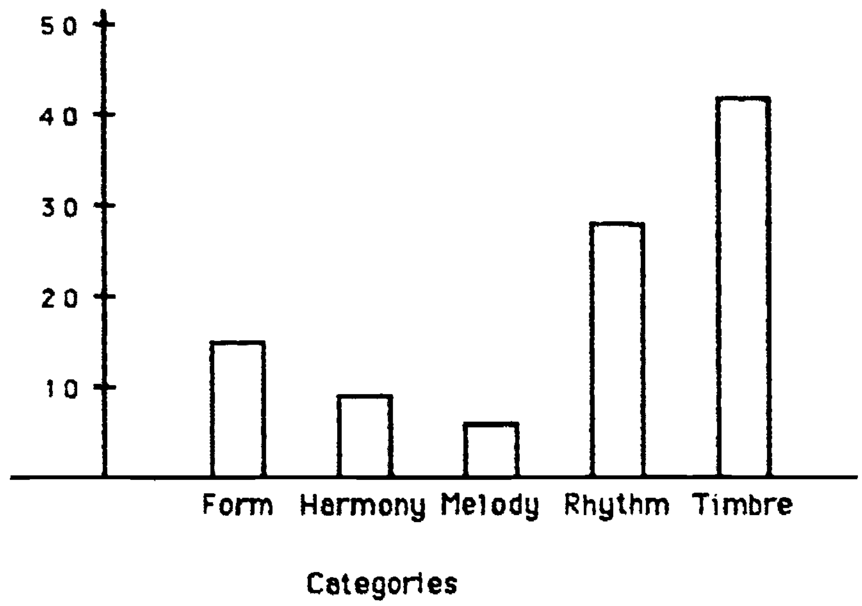
Test Ho: μ(Diagnostic test) $-$ μ(Quiz Average) = 0
vs Ha: μ(Diagnostic test) $-$ μ(Quiz Average) $\neq$ 0
Sample mean(Diagnostic test)=57.250 Sample mean(Quiz Average)=89.571
t-statistic=-8.531 with 54 d.f.
Reject Ho at alpha=0.05

Score reading skill before and after Prof. Buccheri's class the freshmen carry out a listening exercise the very first day of class to get a benchmark. In this exercise, they listened three times to a piece from the ***Water Music*** and took notes on what they were hearing in the piece. These notes were analyzed for parametric (categorical) content, in the areas of timbre, harmony, melody, rhythm, and form (standard categories in style analysis of music). The results are shown in the following tables. Notice that by far the majority of the responses are in the areas of timbre and rhythm--surface features of the music. Other, more "interpreted" features, such as form and harmony, receive scant notice. This was anticipated; at the outset, one expects that listeners will respond to the immediate sonic (timbral) and kinesthetic (rhythmic) aspects of a composition rather than ones requiring more interpretation.

These students then participated in the aural skills classes for two quarters. In the course of these classes, they carried out a variety of exercises dealing with formal analysis, harmonic and melodic dictation, and contextual listening. In the middle of their second quarter of study, they began using the BigEars program as a part of their homework. We were curious as to the kind of learning that would take place in the course of using the program, and have attempted to get some indications of this. One tack we took was to have the students work with another piece from the ***Water Music***, using the puzzle and hierarchy activities, and then perform another content analysis on their view of the piece, taken from a question where they were asked to describe the form of the work. The data collected from this study are shown below. Note that the formal comments increase dramatically (as expected from the bias introduced in the question asked), but that comments concerning timbre and rhythm decrease while those involving harmony and melody increase. This is particularly interesting in that no specific comments regarding melody or harmony were solicited; the increased emphasis on these parameters seems to come along with the focus on form. This is in line with much of what we see in the use of Bigears overall; there is a great deal of incidental learning that takes place (for example, after carrying out the puzzle task students can often sing the entire piece all the way through with few errors--even though they have not been asked to memorize the piece in this way).

The task of dealing with the qualitative data from the BigEars transcript files is still underway, but some overall observations can be made. Let us look at a single typical protocol to see how the a student might proceed.

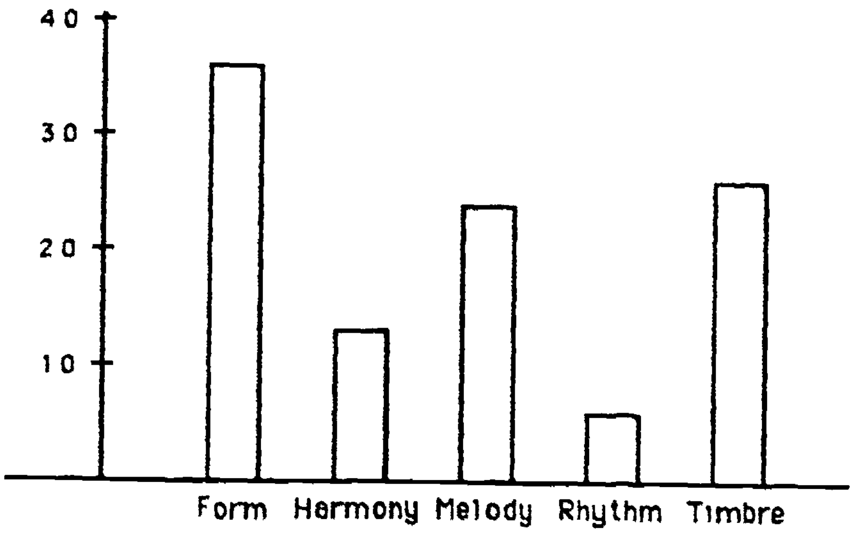
The student protocol we will examine is one from a freshman working with the program for the first time. An overall time-line sketch of the protocol is shown in the following figure. This student is iniitally using the "bulldozer" strategy for learning the piece. In this strategy, one learns the piece up to a certain point, builds a model corresponding to that length of time, starts at the beginning again, learns a little bit more, and has the model grow by accretion. One sees this process at work in the gradual growth of the "Learn" actions--first the whole piece for an overview, then for 12, 18, 24, 40, 49, 69, and finally 124 seconds. These "Learn" sections are coupled with "Seek/Add" pairs which find sections 1, 2, 3, and 4 in turn. This indicates that the accretion process is the student's



Frequency breakdown of **Categories**

Group	Count	%
Form	15	15.0
Harmony	9	9
Melody	6	6
Rhythm	28	28
Timbre	42	42
Total	100	

Content analysis of students' benchmark comments



Frequency breakdown of **Post-Categories**

Group	Count	%
Form	36	34.3
Harmony	13	12.4
Melody	24	22.9
Rhythm	6	5.71
Timbre	26	24.8
Total	105	

Content analysis of students' BigEars comments main way of proceeding--that his overall plan at the outset is to work left-to-right in building his model of the composition. The student's main view of the work at this point is one of a *succession of events*, and this is shown by his working method.

In addition to this goal-driven process we see here, there are elements in the protocol which are more data-driven--where the student is taking advantage of the happenstances of discovery even when they do not fit into the clean left-to-right modelling process. This kind of serendipitous working-out can turn the analysis process from a simple left-to-right modelling to a more relational, synthetic one. This can be seen with the incorporation of sections 10, 8, and 12 in the midst of working through sections 1-4. After placing #12 at the end of the work, the "pillars" of the time-spans are set (the first and last segments of the composition); now a fill-in-the-blank process can take place. Thus, the cluster 4/6/5 is worked out from 851" to 1125", followed by another cluster, 10/9/8. By this time the student knows that there are four segments which follow one another in a certain order, and is able to use both timbral groupings and thematic ordering as data. The final segments are #11 and 7; these are a bit more difficult to place within a section due to their transitional nature, and so are left until last.

The next example shows the protocol described in greater detail. Notice how there are other recurring patterns here, such as the threefold "seek" process before the early "add." This may be due to some kind of memory limitation; each of these threefold patterns takes about the same length of time (30 seconds), whether or not any change was effected to the model. This suggests that some structural limitation, such as memory, may be in operation here.

In the end, this student has been able to reconstruct the work in its entirety. Like other students doing this exercise, he is able to talk a certain amount about the instrumentation and the form of the piece, as well as its overall tonal orientation. The student started off with a simple left-to-right, event-succession model of the work, which was gradually transformed to a more synthetic model by the incorporation of other elements in a nonlinear manner. This shows a genuine growth of method--factors other than those seen as important at first are used in developing a richer model of the composition. It is worth noting that not all students use this data-driven, left-to-right paradigm from the outset. Some decide quickly that it is more expeditious to take notes on the work and its salient features from the outset, eliminating much of the trial-and-error discovery seen above. In effect, this kind of student is using external memory--paper--store her model of the music, rather than internal memory.

Our dissemination efforts are well-underway. Papers on our work have been given at the annual meetings of the Society for Music Theory, the College Music Society, the International Computer Music Conference, and the Music Teachers National Association, and have been published in the Proceedings of the ICMC. By project, the papers and publications we have produced are:

Procedural Modelling of Musical Processes

```
0 mouseDown, shift up, option up, cmd up
bkgnd button "puzzle", 47,77, card "directory"
136.466667 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
139.216667 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
178.133333 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
182.5 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
354.7 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
358.7 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
374.3 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
380.116667 mouseDown, shift up, option up, cmd up
card button "M1", 350,110, card "puzzle"
397.866667 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
399.966667 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
402.083333 mouseDown, shift up, option up, cmd up
card button "S9", 272,110, card "puzzle"
405.716667 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
407.833333 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
409.983333 mouseDown, shift up, option up, cmd up
card button "I9", 389,139, card "puzzle"
425.833333 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
429.883333 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
431.133333 mouseDown, shift up, option up, cmd up
bkgnd button "Air", 60,60, card "puzzle"
443.266667 mouseDown, shift up, option up, cmd up
bkgnd button "SAS", 311,324, card "puzzle"
447.183333 mouseDown, shift up, option up, cmd up
card button "I9", 389,139, card "puzzle"
```

Student protocol excerpt

Time (secs.)	Actions (rept.)	Focus/comments
0-380	Learn (4x)	Whole piece
380-430	Seek	#1
430-447	Learn	About 12"
447-479	Seek/Add	#1
479-501	Learn	About 18"
501-545	Seek/Add	#10
545-582	Seek	#2?
582-610	Learn	About 24"
610-656	Seek/Add	#2
656-700	Learn	About 40"
700-730	Seek/Add	#3
730-781	Learn	About 49"
781-804	Seek/Add	#8
804-851	Seek/Add	#12
851-911	Seek/Add	#4, after #3
911-984	Learn	About 69"
984-996	Seek/Add	#6
996-1026	Seek/Add	#5
1026-1125	Check	Play timeline, about 95"
1125-1147	Check/Reorder	#10
1147-1273	Learn	About 124"
1273-1278	Reorder	#10
1278-1338	Seek/Add	#9
1338-1363	Seek/Add	#8
1363-1387	Reorder/Check	#10
1387-1460	Reorder (9x)	Non-effectual; #9 & #10
1460-1519	Seek/Compare	#11, #7, #11, #6, #11
1519-1522	Add	#11
1522-1527	Check	#11
1527-1618	Add /Check/Reorder	#7, #11
1618-1784	Check	Play timeline for 150"
1784-1904	Reorder	#11
1904-1916	Quit	

Sketch of student protocol for puzzle task

Time (secs.)	Actions (rept.)	Comments
0-380	Learn (4x)	Almost whole piece
380-430	Seek (3x)	#5, #3, #1
430-447	Learn	About 12"
447-466	Seek	# 1
466-479	Add	#1, near front
479-501	Learn	About 18"
501-537	Seek (3x)	#5, #4, #10
537-545	Add	#10, near back
545-582	Seek (3x)	#3, #12, #6
582-610	Learn	About 24"
610-646	Seek (3x)	#11, #8, #2
646-656	Add	#2, after #1
656-700	Learn	About 40"
700-717	Seek	# 3
717-730	Add	#3, after #2
730-781	Learn	About 49"
781-799	Seek	# 8
799-804	Add	#8, before #10
804-843	Seek (3x)	#6, #11, #12
843-851	Add	#12, at end
851-897	Seek (3x)	#7, #5, #4
897-911	Add	#4, after #3
911-984	Learn	About 69"
984-993	Seek	# 6
993-996	Add	#6, after #4 (one open slot)
996-1018	Seek (3x)	#11, #7, #5
1018-1026	Add	#5, between #4 &#6
1026-1125	Check	Play timeline, about 95"
1125-1133	Check	Play #10, on timeline
1133-1147	Reorder	Move #10 after #6 (one open slot)
1147-1273	Learn	About 124"
1273-1278	Reorder	Move #10 down three slots
1278-1330	Seek (3x)	#11, #7, #9
1330-1338	Add	#9, before #10
1338-1356	Seek	# 8
1356-1363	Add	#8, before #9
1363-1373	Reorder (2x)	Slide #10 down one slot
1373-1387	Check	Play #10, on timeline
1387-1460	Reorder (9x)	Non-effectual; #9 & #10
1460-1519	Seek/Compare (5x)	#11, #7, #11, #6, #11
1519-1522	Add	#11, after #5 (one open slot)
1522-1527	Check	Play #11, on timeline
1527-1531	Add (no effect)	Try to put#7, after #11
1531-1541	Check	Play #11, on timeline
1541-1549	Add (no effect)	Try to put#7, after #11 (one open slot)
1549-1562	Reorder	Move #11 down
1562-1581	Add (2x, no effect)	Try to put #7 after #11
1581-1585	Reorder	Move #11 up one slot
1585-1618	Add	Try to put #7 after #11
1618-1784	Check	Play timeline for 150"
1784-1904	Reorder	Move #11 before #12 (one empty slot)
1904-1916	Quit	

Student protocol overview (detailed)

•"Music learning--compositional thinking." International Computer Music Conference 1988, Cologne, West Germany. Published in the **Proceedings of the ICMC 1988.**

Analytic score-reading

•"Pedagogical Alternatives in Music Theory." Guest Lecture Series, University of Wisconsin-Madison, 1990.

• Presentations on "Eyetraining" as member of the Institute for Music Theory Pedagogy 1989, College Music Society, Boulder Colorado.

•"Eye training, analytic reading, and theory anxiety." College Music Society National Conference 1988, Santa Fe.

•"Pedagogical Alternatives in Music Theory." Guest Lecture Series, Bowling Green State University, 1987.

•"The score as code: Eyetraining for analysis and theory anxiety." Society for Music Theory National Convention 1987, Rochester, New York.

•"Eyetraining." Society for Music Theory National Convention 1987, Rochester, New York.

•"Sight reading for analysis." Music Teachers National Association National Convention 1987, New York.

Analytic listening

•"Analysis by ear and eye: Cognitive approaches to the discovery of musical structure." Guest Lecture Series, University of Michigan, 1990.

•"Structure and strategy in analytic listening." Guest Lecture Series, Eastman School of Music, 1990.

•"A new approach to teaching analytic listening." College Music Society National Convention 1989, St. Louis, Missouri.

•"A computer system for learning analytic listening." International Computer Music Conference 1989, Columbus, Ohio. Published in the **Proceedings of the ICMC 1989.**

•"Computer-based learning: Models and lessons for computer music systems." International Computer Music Conference 1989, Columbus, Ohio. Invited paper. Published in the **Proceedings of the ICMC 1989.**

•"A computer-based approach to teaching analytic listening." Society for Music Theory National Conference 1989, Austin, Texas.

•"Computer-assisted instruction in analytic listening." Guest Lecture Series, Indiana University, 1989.

Interest in the analytic listening and score analysis projects has come from an increasingly large number of institutions beyond Northwestern. Schools interested in using the analytic listening software include Yale, the Eastman School of Music, the University of Michigan, Indiana University, the University of Illinois, and Arizona State University, among others; the score-analysis project has attracted attention from a like number of institutions.

For the near future, our plans are to publish the analytic listening and score analysis materials as textbooks and as computer-assisted-instruction software, and to continue with developing full curricula around them. Our evaluation efforts will also continue to some degree. Prof. Ashley has made studying the analytic listening transcripts his research project for the remainder of 1990, and is in the process of writing a major article on this topic.

Summary and Conclusions

We have gained some hard-won insights which are probably obvious to all at FIPSE but were news to us. First, bringing about significant change in an institution at any level is very difficult. It takes great amounts of time and effort, and seems to hinge at least as much on personal and political factors as it does on the educational/curricular substance under discussion. We had not taken into account the need to develop the grant in the widest possible circles and to continue to help those outside the grant proper feel included rather than threatened, so that institutionalization of the grant results could be enhanced. Finally, we had not intially anticipated the degree to which other institutions might respond coolly or even negatively to a complete and hermetically-sealed curriculum which left little room for individual faculty freedom, as opposed to providing more flexible tools which the faculty member could use on his own as he wished.

At the outset, we overestimated the amount we would be able to accomplish in the grant, especially in terms of developing complete curricula around this multidimensional model of music learning. We shifted from our original all-encompassing model to one involving more focused tools, and have thus made our work more adaptable to other institutions. Although the tools for more successful multimedia applications are now much more mature than they were four years ago, our advice to others would be to develop well-targeted systems--especially those including an authoring system or other end-user capability--rather than attempt comprehensive solutions.