An Empirical Estimate of Student Growth in Beginning Music Theory: Results and Pedagogical Implications

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INTRODUCTION

Placement tests for incoming freshmen in departments of music are common at many universities. These tests assess students' knowledge of basic music theory principles and are used by department administration to assign students to music theory courses which will provide them the opportunity for maximum personal growth.

These tests cover what we describe as "beginning music theory." This conception includes constructs such as scales, key signatures, and chord root, quality, and inversion. In addition to these more cognitive constructs, basic aural abilities such as rhythmic and melodic dictation also fall under this rubric.

Music theory has traditionally been the bane of freshmen music students' existence. Many students enter music programs with years of performance training with a particular instrument and a love of music performance, unaware that the field of music theory even exists. Imagine their surprise when the road to graduation lies blocked by harmonic analysis, formal analysis, and other heady stuff that at first glance has little or nothing to do with performing. Freshman music theory courses account for more program attrition than any other factor (ref, 19xx).

The purpose of the study reported here was to provide a clearer picture of the beginning music theory content domain. This enhanced picture would support curricular innovations that could bring novices to an acceptable level of proficiency in a more enjoyable and efficient manner than current remedial courses. The study also served to deepen our understanding of a new research methodology called "Quantitative Domain Mapping" (Wiley, 2000).

METHODOLOGY

Quantitative Domain Mapping

Wiley (2000) describes the Quantitative Domain Mapping (QDM) methodology as a synthesis of four existing instructional design theories: Reigeluth's (1983, 1999) Elaboration Theory, Gibbons and associates' (1995) Work Model Synthesis procedure, van Merriëboer's (1997) Four-Component Instructional Design model, and Bunderson and associates' Domain Theory (2001). The goal of the methodology is to begin to provide a clearly delineated "understand[ing of] the construct-relevant sources of task difficulty" with in the domain being studied (Messick, 1995). A more precise understanding of the difficulties of and relationships between tasks within the content domain give an instructor or instructional designer additional data with which to make design decisions, such as those involving content scope and sequencing.

The methodology itself is comprised of two major components: theory building and theory improving, viewing theory improvement as an on-going commitment on the part of the researcher. The following simplified description is adapted from Wiley (2000).

Theory Building

Identify major constructs. What does expert performance in the domain look like? What tasks do experts perform when engaged in domain performance? Construct identification is an iterative analysis and synthesis process. First the researcher uses task analysis (Merrill, 1976), skill decomposition (van Merriënboer, 1997), or another job analysis technique to break the content domain down into meaningfully distinguishable constructs. Then she employs work model synthesis techniques to recombine these tiny, decontextualized objectives into meaningful, real-world performances. The analysis results in a set of specifications for integrated performances of clearly identified constructs within the content domain.

In this study we identified a low level set of constructs (such as "Correctly identify notes written on a staff") and integrated them into the following performances.

1. Identify or construct scales given key signatures
    a. Major
    b. minor
2. Identify or construct key signatures
    a. Major
    b. minor
3. Identify or construct triads
    a. Major
    b. minor
    c. diminished
    d. augmented

4. Hear and write intervals
5. Take melodic dictation

These integrated performances formed the first rough draft of the QDM.

Separate constructs into categories. The next step in the QDM methodology directs the researcher to identify major categories of expert performance within the domain and group the integrated performances accordingly. For example, Strong-Krause (2001) identified four major types of expert performance in the domain of English language acquisition: reading, writing, speaking, and listening.

In this study we hypothesized the existence of two types of expert performance and divided the integrated performances accordingly.

1. Cognitive skills
    a. Identify or construct scales given key signatures
        i. Major
        ii. minor
    b. Name key signatures
        i. Major
        ii. minor
    c. Identify or construct triads
        i. Major
        ii. minor
        iii. diminished
        iv. augmented
2. Aural skills
    a. Hear and write intervals
    b. Take melodic dictation

This elaboration was the second theorized version of the QDM.

Estimate within-category item difficulty orderings. As the final part of the theory building process, the researcher estimates the difficulty of each performance and orders the performances within each category by difficulty. The previous separation of performances into categories helps avoid transitivities and other undesirabilities in the data, providing a clearer picture of the domain.

We hypothesized the following difficulty orderings from simplest to most difficult within the Cognitive Skills category: Identify or construct scales given key signatures (easiest), Name key signatures (moderate), and Identify or construct triads (most difficult). No difficulty ordering was hypothesized for the Aural Skills category.

With a fairly robust domain map hypothesized, the researchers began the theory improvement portion of the methodology.

RESULTS

Theory Improving

Design and administer test items. Theory improvement involves empirically testing and tuning the theorized domain map, and alternately tuning and improving the empirical instruments.

Bunderson (2000) espouses the use of "construct-valid testlets," sets of three to five items focused around assessing learner ability on a single construct, for purposes of theory improvement. Such multi-sampling approaches to assessment provide snapshots of learner ability relatively free of guessing bias. More importantly, the approach encourages instrument designers to focus carefully on each of the constructs to be assessed, ensuring that each construct of interest is adequately represented in the final assessment instrument.

Because we were working with a department-standard placement exam, the researchers were unable to control for guessing and other construct-invalid biases through the use of construct valid testlets. Instead, we "reverse engineered" the placement test to discover those constructs assessed by the exam. We are relieved to report that the exam provided adequate coverage of the beginning music theory constructs previously described. The results reported below are based on the described QDM analysis of 68 incoming freshmen placement tests from a major Eastern university's department of music.

Factor analyze results. In order to improve initial estimates of the major categories of expert performances within the domain, assessment results can be explored using factor analytic techniques such as principal components analysis or smallest space analysis. Empirically observed factors can be compared against hypothesized factors and adjustments to either theory or instrument can be made accordingly.

The first five components extracted in the principal components analysis performed on the placement test data are displayed in Table 1. Our initial hypothesis of two categories of performance types, one corresponding to Cognitive Skills and another to Aural Skills, was only partially borne out. Three components were discovered using a Principal Components Analysis of the placement test data with a Promax rotation in SPSS 9.0. Of these three, the third was clearly associated with the Aural Skills items on the placement test while the first two components seem to correspond to levels of cognitive development. The first component seems to correspond to basic musicianship (such as the ability to identify major key signatures and to construct major scales) while the second corresponds to more advanced cognitive skills, such as the ability to differentiate between harmonic and melodic forms of minor scales. Since the N for this study was smaller than desirable, and since spurious "difficulty level" factors often emerge in item factor analysis studies, the hypothesis of one cognitive growth dimension was not rejected.

Table 1

Principle Components in Music Theory Placement Test Data

	Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	5.965	45.882	45.882
2	1.479	11.378	57.259
3	1.313	10.098	67.357
4	.822	6.322	73.679
5	.658	5.062	73.679

IRT item difficulty analysis. In order to improve initial hypotheses regarding the relative difficulties of items, item response theory (IRT) can be used to generate empirical estimates of item difficulty. While the initial hypotheses were qualitative, these empirical estimates can be used to confirm or challenge the difficulty ordering of items within major categories of performance types. Because the intervals and melodies (Aural Skills items) used in the placement test varied over the duration of the study, the difficulties of only Cognitive Skills items could be meaningfully estimated. Table 2 presents the item difficulties derived from an IRT analysis of the placement exam data using QUEST.

Table 2

Cognitive Skills Item Difficulties as Estimated Using QUEST

Item Description	Difficulty Estimate
Write A major scale with key signature	-1.62
Write A flat major scale with key signature	-0.81
Write a melodic minor with key signature	2.15
Write c harmonic minor with key signature	3.22
Identify the name of this major key (E flat)	-1.75
Identify the name of this minor key (b)	-0.08
Identify the name of this minor key (f)	0.63
Identify the name of this major key (G)	-2.29
Identify the triad as M, m, o, or + (M)	-1.14
Identify the triad as M, m, o, or + (m)	0.03
Identify the triad as M, m, o, or + (+)	1.62
Identify the triad as M, m, o, or + (M)	-0.92
Identify the triad as M, m, o, or + (o)	0.63

Note. Items are grouped according to their type, scale construction items in the first group, key identification in the second group, and triad identification in the third.

As the results in Table 2 demonstrate, the proposed difficulty ordering of Identify or construct scales given key signatures (easiest), Name key signatures (moderate), and Identify or construct triads (most difficult) fails completely. Each type of item displays a wide variety of difficulties, with each group ranging from –1.14 at easiest to 0.63 at most difficult. Further inspection of the table data reveals that the item characteristic most closely correlated to difficulty is not item type, but item quality. That is to say that item difficulty depended directly upon the degree to which examinees were required to understand the cognitive constructs major, minor, diminished, and augmented.

Revise theory and/or instruments and retest. The final step in the QDM methodology is the retuning of the initial QDM based on the empirical data, followed by an iteration of the theory improvement sequence. This study only reports results of the first iteration of the QDM process. Even though the hypothesized QDM significantly differed from the empirical data, the study is extremely significant in its pedagogical implications.

DISCUSSION

Pedagogical Implications

The “ready, fire, aim” approach espoused in the QDM methodology can make for results like those seen above. Frighteningly, the theorized categories and item difficulties reflect common beginning music theory pedagogic practice. Scales are learned first, followed by key signatures, followed by triads. The results of this study, particularly the item difficulty estimates, suggest that an alternative instructional sequence may be more effective and enjoyable.

Zone of proximal development. Vygotsky’s (1978) zone of proximal development (ZPD) represents the set of tasks a child can complete with an adult’s assistance, as opposed to those they can successfully perform alone. This result has been generalized to the cases of learner and teacher, so that the ZPD can be seen as representing the set of tasks a learner can successfully perform with expert guidance, as opposed to those tasks the learner is capable of completing alone. Tasks within a learner’s ZPD are those performances currently “just out of reach” of the learner alone, and Vygotsky suggests that these tasks which the learner is not quite capable of performing alone are the most appropriate performances to learn next.

The QDM provides an empirical grounds for ZPD-style sequencing of tasks within a given content domain. Without such a methodology, instructors or instructional designers are left to “guesstimate” learners’ growth paths through the domain in question. While the QDM represents a mean growth path and will not fit every learner perfectly, the map does provide empirically grounded data with which to make results regarding which performance may be next closest to the learner’s current ability.

A ZPD interpretation of the results of the difficulty estimates of items on the placement exam might suggest a straightforward simple-to-complex ordering of items within each category. Following ZPD would result in micro-level sequencing changes. That is to say that following ZPD, designers would most likely change the order in which item types within a category are presented to the learner. This step provides a much greater resolution than our initial difficulty estimate, which ordered only the large item groups. The initial sequencing of Identify or construct scales given key signatures (easiest), Name key signatures (moderate), and Identify or construct triads (most difficult) would be deepened a level to read: Identify major key signatures, Construct major key signatures, Identify minor key signatures, Construct minor key signatures, etc. Such a modification would be a significant improvement to our current map.

Cognitive load theory. Cognitive Load Theory (Chandler & Sweller, 1992; Paas & van Merriënboer, 1993) provides instructors and instructional designers with a crucial insight: the human mind has a limited processing capability, and learning will occur only in proportion with the amount of processing dedicated to instructionally-relevant tasks. For example, the brainpower a learner dedicates to navigating online instructional materials, simultaneously monitoring Napster downloads, and trying to get the proper viewer plug-in installed so that they can view an interactive molecular simulation is not available for learning because it is being utilized administratively. Van Merriënboer (1997) distilled Cognitive Load Theory into two principles:

1. Prevent cognitive overload. This principle is in agreement with the common guideline to pose problems to learners that are just beyond their level of competence.
2. Redirect attention by (a) decreasing extraneous cognitive load, and (b) increasing the cognitive load relevant for learning. (p. 186)

Designers frequently attempt to avoid cognitive overload by utilizing a simple-to-complex problem sequencing strategy, as suggested by ZPD research. Such is the case with the redesigned beginning music theory sequence suggested above: simple scales, moderate scales, difficult scales, followed by similar sequences for key signatures and triads. However, van Merriënboer rejects this micro-level sequencing strategy as violating the second principle of CLT, and presents research (Paas & van Merriënboer, 1994a, 1994b) demonstrating the superiority of "low-load problem formats combined with high-variability sequencing strategies" (p. 190).

Applied to the beginning music theory domain, this recommendation translates into teaching low difficulty items of a variety of types in order to promote better transfer learning. In other words, the simple-to-complex sequencing strategy would be applied to cut across large groups of item types, with the first sequence of items a learner would encounter being randomly drawn from a pool of easy key signature, scale, and chord items (appearing in the red band in Figure 1). As learners mastered these items, they would then encounter slightly more difficult items from each group (those in the blue band in Figure 1). Finally, learners would be introduced to the most difficult concepts in the domain (those in the green band in Figure 1). van Merriënboer (1997) refers to this across group sequencing strategy as "meso-level sequencing."

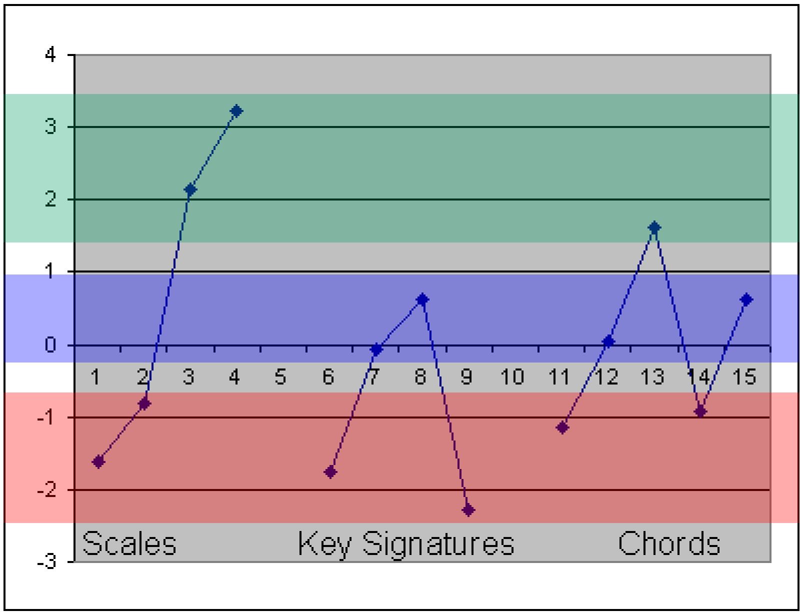

Figure 1. Item difficulties for scale, key signature, and chord items from the placement exam. Items of the same type are connected. Items in the same color band are of similar difficulty.

Elaboration Theory. Reigeluth's (1983, 1999) Elaboration Theory approach to instruction was developed partially in response to weaknesses with computer-based learning research at Brigham Young University. Students using the TICCIT system (Bunderson, 1973) were able to achieve significant mastery of individual skills but failed to demonstrate the ability to adequately combine these skills into integrated performances.

The Elaboration Theory approach describes a method of sequencing instruction that facilitates integration of the component skills students are learning. In addition to the recommendations above (like working with the simplest tasks from each item category first), Elaboration Theory recommends engaging students with a real world, though simplified, example of the target performance from the very beginning of instruction. This simplified problem, called an "epitome," should be the simplest form of the problem that an expert would engage in the real world. This integration-from-the-first approach adds to learner motivation, as students see the manner in which the individual skills are used together to accomplish valuable purposes.

Our purpose in teaching music theory is not to enable students to identify major chords and harmonic minor scales. Our purpose is to allow students to competently perform harmonic, formal, and other analyses of music they are performing in order to deepen their appreciation and understanding, and ultimately to improve their performance.

Elaboration Theory employs a technique called the Simplifying Conditions Method. The SCM directs designers of instruction to find the simplest version of the target task an expert has ever performed, several other major versions of the task, and the conditions that distinguish the task versions of varying difficulties (Reigeluth, 1999). Once again, the QDM provides empirical evidence useful in making these discoveries. From the categorization of domain constructs into types, and the factor analytic investigation of the hypothesized categorization, the meaningful conditions constraining task difficulty can be deduced. This categorization will be immensely useful to designers of epitomes, as the empirical evidence regarding the meaningful dimensions of the task/problem space give the designer a checklist with which to assure that the epitome is really a whole version of the task, and not a subtask. Analyses of construct difficulties within types provide the designer with insights regarding the manner in which the conditions should be manipulated in order to produce increasingly difficult versions of the task, until finally the target performance is achieved.

Applying a QDM-based Elaboration Theory approach to the beginning music theory domain, instruction would revolve around an epitomized harmonic analysis. Almost any popular song could serve the purpose, with only two or three major chords to be analyzed. Major key signatures, scales, and chords could all be taught within the context of the analysis itself, as learners engage the simplest form of the task an expert has ever encountered. Slightly more complex musical pieces would be introduced for analysis gradually, along with the additional instruction necessary for the completion of their analysis. Increases in difficulty would be achieved by manipulating the task characteristics according to the empirical estimates of difficulty; so that pieces presented for later analysis could include minor chords, diminished chords, and eventually augmented chords (see Table 2).

CONCLUSION

We have presented a Quantitative Domain Map of the beginning music theory domain and argued that the type of understanding facilitated by QDM studies can be immensely useful to designers of instruction, whether they be professional instructional designers or teachers of primary grades. The empirical map of the domain agreed only moderately with a domain map hypothesized from current beginning music theory teaching practice. We demonstrated how the QDM study of the beginning music theory domain could improve beginning music theory instruction with examples of ways the study could inform instructional design according to two principles and an instructional design theory. We will report the results of the implementation of the new instructional design in a future publication.

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