

**SURVIVING SET THEORY:
A PEDAGOGICAL GAME AND COOPERATIVE LEARNING APPROACH
TO UNDERGRADUATE POST-TONAL MUSIC THEORY**

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Abstract

Undergraduate music students often experience difficulties when they first encounter pitch-class set theory, an analytical methodology very different from those they have studied previously. With the goal of fostering good will and openness toward studying post-tonal music, I adapt the reality competition show *Survivor* to frame a four-week unit on set theory and provide empirical results of Set Theory Survivor via student questionnaires and comments. The results of the study confirm that by combining the peer support of cooperative learning with the motivational force of constructive intergroup competition and the fun of a pedagogical game, Set Theory Survivor presents an effective approach to a difficult subject and provides a creative tool to enhance the pedagogy of pitch-class set theory.

Foundations of Set Theory Survivor

The pedagogy of pitch-class set theory as a means of post-tonal music analysis poses a number of problems, not the least of which are the overtly mathematical features of set theory and the dissonance of much of the repertoire studied. In light of the unfamiliar, frequently dissonant construction of twentieth-century atonal music, Jena Root notes that students may mistakenly believe this new repertoire is devoid of beauty and order.¹ The trepidation students may experience when confronted with music seemingly independent of any particular syntax can be amplified by the diversity of post-tonal music in which, as Courtenay Harter observes,

¹ Jena Root, "Stravinsky's 'Spring Rounds': Primer for a Twentieth-Century Musical Aesthetic," *Journal of Music Theory Pedagogy* 24 (2010): 13.

compositional techniques and harmonic practices—no longer bound by tradition—vary widely from one composer to the next.² Peter Silberman aptly describes post-tonal music as a “foreign language” to many undergraduate students.³

In addition to students’ resistance toward studying music they might expect to sound like “cacophonous nonsense,” Stanley Kleppinger realizes that the explicit connection between set theory and mathematics can be intimidating to students.⁴ Because the terminology and applications of set theory differ considerably from the methods of analysis with which they are already familiar, students experience a “steep learning curve.”⁵ However, Joseph Straus offers hope to perplexed students:

Despite its occasionally forbidding appearance, atonal set theory is not particularly complicated, at least in its basic applications. No high-powered computers or advanced degrees in mathematics are needed—just a commitment to twentieth-century music, the ability to add and subtract small integers, and some good will.⁶

Kleppinger concludes that students who learn to engage unfamiliar music with the analytical tools appropriate to that repertoire are rewarded with broadened tastes and a greater openness to new aesthetic experiences.⁷

With the goal of fostering good will and openness toward studying post-tonal music, I propose an innovative approach to teaching pitch-class set theory in the undergraduate core

² Root, ““Spring Rounds,”” 13; Courtenay L. Harter, “Bridging Common Practice and the Twentieth Century: Cadences in Prokofiev’s Piano Sonatas,” *Journal of Music Theory Pedagogy* 23 (2009): 77.

³ Peter Silberman, “Post-Tonal Improvisation in the Aural Skills Classroom,” *Music Theory Online* 9, no. 2 (July 2003): [1].

⁴ Stanley V. Kleppinger, “Strategies for Introducing Pitch-Class Set Theory in the Undergraduate Classroom,” *Journal of Music Theory Pedagogy* 24 (2010): 131–32. By way of illustration, Kleppinger describes a conversation he had with a student who, despite performing above the average in Kleppinger’s undergraduate theory course, expressed anxiety about studying the ““atonal music with all the math in it.””

⁵ Kleppinger, “Strategies,” 134–35.

⁶ Joseph N. Straus, “A Primer for Atonal Set Theory,” *College Music Symposium* 31 (1991): 2.

⁷ Kleppinger, “Strategies,” 154.

curriculum.⁸ This approach adapts the popular CBS television show *Survivor* to frame a four-week unit on set theory.⁹ My version of *Survivor*, Set Theory Survivor, promotes peer tutoring and student learning within the enjoyable framework of a pedagogical game. During Set Theory Survivor, as on the show, students of different achievement levels work together in small groups, or “tribes,” to complete exercises such as finding the normal form of pitch-class sets, calculating interval-class vectors, and determining pitch-class invariance on worksheets called “challenges.” However, in an important modification to the structure of the show, no students are voted out of their tribes. At the end of the unit, all members of the tribe that earned the highest cumulative average score on the challenges receive non-academic prizes in the form of modest gift cards. While students’ grades are based solely on their own work, the game element promotes peer mentoring through cooperative learning, and inspires constructive peer pressure that motivates all students to do their best. Aspects of the game designed to enhance student enjoyment and build tribe unity include tribe names, a customized logo, and an opening credits video.

By framing course material with elements of popular culture, pedagogical games like Set Theory Survivor invite students to invest more fully in their education through active learning and new avenues of thought.¹⁰ For example, pedagogical games in the fields of business and sociology help students understand complexities of customer relationships, as well as sensitive

⁸ While this approach is primarily concerned with labeling and abstract theory, the ultimate goal is to help students understand the different dialects of the “foreign language” of post-tonal music.

⁹ CBS, www.cbs.com/shows/survivor/. On *Survivor*, sixteen to twenty contestants are divided into two or more tribes that spend several weeks living in a remote (often tropical) location with limited food and supplies. Tribe members work together to survive and compete against the other tribe, or tribes, in a variety of mental and physical challenges. Contestants are gradually eliminated from the game through voting at Tribal Council; the last remaining contestant wins the title of Sole Survivor and one million dollars.

¹⁰ According to Jennifer Faust and Donald Paulson, active learning consists of “any learning activity engaged in by students in a classroom other than listening passively to an instructor’s lecture.” “Active Learning in the College Classroom,” *Journal on Excellence in College Teaching* 9, no. 2 (1998): 4.

issues associated with race and ethnicity.¹¹ Dan Pence argues that the incorporation of familiar television shows can “reduce students’ unfamiliarity with or even resistance to addressing abstract material by framing these concepts in their personal experiences.”¹² Forerunners of Set Theory Survivor in music theory pedagogy include Jeff Gillespie’s and Lora Gingerich’s respective adaptations of Bingo and Poker to college-level theory classes,¹³ Whitney Berry’s adaptation of *Survivor* to a unit on music theory fundamentals,¹⁴ and my use of pedagogical games such as part-writing relay races, interval tag, and chord dictation tournaments in my own theory teaching. While important, these precedents either focus on topics outside the purview of set-theoretical analysis or occur within a single class, leaving the potential for longer-term

¹¹ Venkatapparao Mummalaneni and Soumya Sivakumar, “Effectiveness of a Board Game in Fostering a Customer Relationship Orientation Among Business Students,” *Journal of Relationship Marketing* 7, no. 3 (2008): 257–73; Warren Waren, “Using *Monopoly* to Introduce Concepts of Race and Ethnic Relations,” *The Journal of Effective Teaching* 11, no. 1 (2011): 28–35.

¹² Dan Pence, “‘I’ll Take Ideology for \$200, Alex’: Using the Game Show *Jeopardy* to Facilitate Sociological and Critical Thinking,” *Teaching Sociology* 37 (April 2009): 171.

¹³ Lora L. Gingerich, “Pitch-Class Poker,” *Journal of Music Theory Pedagogy* 5, no. 2 (Fall 1991): 161–78. Using the structure and rules of traditional poker, Gingerich’s adaptation is designed to help its players better understand the concepts of interval-class vectors, supersets, and subsets (161, 177). A variety of pedagogical games appear in Jeff Gillespie’s ten-day “Theory Camp” for incoming freshman music majors as well as the four-day version of Theory Camp developed by Rebecca Atkins and Michael Murray. Jeff Gillespie, “Welcome to Theory Camp! More Than Simple Remediation,” *Journal of Music Theory Pedagogy* 14 (2000): 49, 54–55; Rebecca Atkins and Michael Murray, “Revisiting Theory Camp: Improving Student Success in Freshman Theory,” *Music Theory Pedagogy Online* 1 (2013): 1, 12, 14.

¹⁴ Whitney Berry, “Surviving Lecture: A Pedagogical Alternative,” *College Teaching* 56, no. 3 (Summer 2008): 149–53; Whitney Berry, “Beyond Survival: Using Games to Thrive in Lecture,” in *Exploring Learning & Teaching in Higher Education*, ed. Mang Li and Yong Zhao (Berlin: Springer, 2015): 45–68. According to Berry, the time students spend on “Music Theory Island” leads to increased confidence and “a deeper understanding of and fluency with the fundamental concepts of the discipline.” Students also obtain substantial emotional and social support—bordering on that of a “pseudo family”—from their fellow tribe members (“Beyond Survival,” 65, 47, 51). Students who find the process of learning theory fundamentals tedious or are overwhelmed by the steep learning curve of studying music theory for the first time may benefit most from the interactive format and peer support system of the game. Other pedagogical adaptations of *Survivor* appear in fields such as medicine and mathematics. Mary Howard, Heidi Collins, and Stephen DiCarlo, “‘Survivor’ Torches ‘Who Wants to Be a Physician?’ in the Educational Games Ratings War,” *Advances in Physiology Education* 26 (2002): 30–36; Robert Burks, “Survivor Math: Using Pop Culture to Enhance Learning Mathematics,” *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies* 21, no. 1 (January 2011): 62–72.

connections among students underdeveloped. Set Theory Survivor, on the other hand, engages set theory during a four-week unit of a sophomore-level theory course.

Set Theory Survivor is structured as an intergroup competition. By combining intragroup cooperation with competition between groups, intergroup competition blends the social benefits of cooperative learning with the motivational force of constructive competition in a powerful pedagogical synthesis. According to David Johnson and Roger Johnson, the benefits of intergroup competition include help and support from one's teammates, greater enjoyment of the competition, and decreased responsibility for losing. Thus, the pressure students feel to achieve is properly balanced with a commensurate degree of support from their peers.¹⁵ Provided that all groups have generally equal chances of winning, Robert Slavin argues that intergroup competition supplies the students in each group with a challenging, but attainable, standard of success that renders the competition both motivating to students and palatable to instructors.¹⁶

The theoretical underpinnings of the cooperative-learning aspect of Set Theory Survivor synthesize social cohesion and social motivation as students develop supportive peer relationships while striving to win the offered prize. According to Slavin (whose own work reflects the perspective of social motivation), scholars with a motivationalist orientation emphasize the reward or goal structure within which students operate, holding that the engagement of students in learning processes such as planning and helping is fueled by their "motivated self-interest." In contrast, the social cohesion perspective, exemplified by the work of Johnson and Johnson, primarily attributes the effects of cooperative learning on student achievement to the group's internal cohesiveness. From this standpoint, students help their group

¹⁵ David W. Johnson and Roger T. Johnson, *Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning*, 5th ed. (Boston: Allyn and Bacon, 1999): 145, 208.

¹⁶ Robert E. Slavin, *Cooperative Learning*, Research on Teaching Monograph Series (New York: Longman, 1983): 36.

mates out of altruistic motives and a sense of belonging.¹⁷ According to Johnson and Johnson, the effectiveness of cooperative-learning groups proceeds from five elements of cooperative learning: positive interdependence, face-to-face promotive interaction, individual and group accountability, social skills, and group processing. Each element is important; however, Johnson and Johnson maintain that positive interdependence—the mutual dependence of individual success and the success of the group—is essential for cooperation to exist.¹⁸

All five of Johnson and Johnson's core elements of cooperative learning are present in Set Theory Survivor, and positive interdependence, the most important of these elements, appears in multiple forms throughout the game. Students in each tribe embrace identity interdependence as they rally around a shared tribe name and color. Tribe members also sit together in class, thus tapping into positive environmental interdependence. As students work together toward the common aim (goal interdependence) of earning the highest cumulative tribe score on the challenges and thereby winning a non-academic prize (reward interdependence), they engage outside enemy interdependence by competing against other tribes. Positive interdependence within each tribe inspires promotive interaction (facilitating each other's success) as tribe members share explanations and answers. Students remain individually accountable for their own learning, because the scores for an individually completed challenge still contribute to the cumulative scores of their tribes and therefore affect the outcome of the game. In order to help their tribes function optimally, students must employ appropriate social

¹⁷ Robert E. Slavin, "Classroom Applications of Cooperative Learning," in *APA Educational Psychology Handbook*, vol. 3: Application to Learning and Teaching, ed. Karen R. Harris, Steve Graham, and Tim Urdan (Washington, D.C.: American Psychological Association, 2012): 360.

¹⁸ Johnson and Johnson, *Learning Together*, 75, 78, 29. Identifying nine types of positive interdependence (goal, reward, resource, role, identity, environmental, fantasy, task, and outside enemy interdependence), Johnson and Johnson recommend that multiple forms of positive interdependence appear within each cooperative lesson (77, 29).

skills in their interactions with fellow tribe members. Finally, Set Theory Survivor includes elements of questionnaire- and discussion-based group processing at the end of the unit.

In this article, I describe my implementation of Set Theory Survivor as a classroom-based research study and present empirical results of Set Theory Survivor via student questionnaire responses and comments.¹⁹ Students reported considerable learning during Set Theory Survivor, which is confirmed by the statistically significant increase in their ability to perform specific set-theoretical operations from pre-test to post-test. The majority of students enjoyed the game-like format of the unit, and students described Set Theory Survivor as a “bonding experience” that facilitated an increasingly open dialogue within the class. The results of the study confirm that by combining the peer support of cooperative learning with the motivational force of constructive competition and the fun of a pedagogical game, Set Theory Survivor presents an effective approach to a difficult subject and provides a creative tool to enhance the pedagogy of pitch-class set theory.

Set Theory Survivor in the Classroom

Set Theory Survivor occupied weeks eight through eleven of Theory IV, the final course in the undergraduate theory core at The Ohio State University.²⁰ The close alignment of educational elements (lectures, practice exercises, graded worksheets, working in groups) and research elements (consent process, pre-test and post-test questionnaires, class videotaping) in

¹⁹ An extended discussion of Set Theory Survivor and its results appears in my dissertation, “Surviving Set Theory: A Pedagogical Game and Cooperative Learning Approach to Undergraduate Post-Tonal Music Theory,” Ph.D. diss., The Ohio State University, 2015.

²⁰ Course materials were drawn from the following texts: Stefan Kostka, *Materials and Techniques of Post-Tonal Music*, 4th ed. (Upper Saddle River, NJ: Pearson, 2011); Miguel Roig-Francolí, *Understanding Post-Tonal Music* (New York: McGraw Hill, 2008); Joseph Straus, *Introduction to Post-Tonal Theory*, 3rd ed. (Upper Saddle River, NJ: Pearson, 2005).

Set Theory Survivor thoroughly integrated this study into the fabric of the course.²¹ All fifteen students enrolled in my section of Theory IV chose to participate in the study.²² Throughout the unit, I observed the interactions of students during class and documented my observations in a teaching journal. I videotaped class activities to enhance the detail and accuracy of my observations. Students completed two paper questionnaires: a pre-test questionnaire at the beginning of the unit and a post-test questionnaire at the end of the unit. Both questionnaires consisted of open-ended questions as well as questions presented as statements to which students responded by circling their answers on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7).²³ At the end of the unit, I facilitated a class discussion to examine students' experiences with Set Theory Survivor.

Tribe Composition

The most important connection between *Survivor* and Set Theory Survivor was the grouping of students into cooperative-learning teams called "tribes." The metaphor of tribal membership promoted positive interdependence and fostered supportive relationships among the members of each tribe through a sense of belonging.²⁴ Tribes were heterogeneous with regard to achievement; each tribe contained at least one higher-achieving, one medium-achieving, and one

²¹ Two of the research elements—class videotaping and obtaining student feedback via questionnaires—are also common in educational contexts.

²² This study was approved by the Institutional Review Board at OSU. All participating students provided their consent via a single-question survey on the online class server. Another section of Theory IV, which met at the same time as mine, was available to students as an alternative to participating in the study.

²³ For a complete listing of the pre-test and post-test questions and their motivations, see Appendix A.

²⁴ According to Elisa Robyn, the metaphor of a "tribe" can inspire tribe members to seek "the greater good of the group" without losing sight of the "vital role" played by every individual. "Creating Tribes," *College Teaching* 48, no. 2 (Spring 2000): 65. My use of the term "tribe" emphasized its connotations of positive interdependence and belonging without implying stereotypes of primitivism.

lower-achieving student.²⁵ To the extent permitted by the gender balance of the class, tribes were also heterogeneous with regard to gender.²⁶ The class was divided into three four-person tribes and one three-person tribe.²⁷ On *Survivor*, each tribe receives a name inspired by the locale. Reflecting the focus of the unit, each Set Theory *Survivor* tribe was named after a prominent twentieth-century composer whose oeuvre included atonal compositions. The four composers selected were Schoenberg, Bartók, Stravinsky, and Berg. The name of the third member of the Second Viennese School, Anton Webern, was not assigned to a tribe; because the music-analytical portions of the unit focused on several of his compositions, naming a tribe after Webern might have implicitly privileged that tribe.

Challenges

A prominent part of *Survivor* is the undertaking of physical or mental “challenges.” In Set Theory *Survivor*, challenges consisted of paper worksheets containing a variety of exercises related to pitch-class set theory. Students completed a total of seven graded challenges and one ungraded reward challenge during Set Theory *Survivor*.²⁸ With the exception of Challenge 7, which students completed individually to demonstrate their mastery of course material, students

²⁵ Students were assigned to tribes on the basis of their cumulative course averages following the midterm examination. No rankings of students within their tribes were announced.

²⁶ The class of fifteen students was made up of nine women and six men. Two tribes included two women and two men; one tribe included three women and one man; and one tribe included two women and one man.

²⁷ The reason for dividing the class into four tribes of varying sizes instead of five three-member tribes was two-fold. First, the use of predominantly four-member tribes provided more of a cushion to offset occasional student absences. If one member of a four-person tribe was absent, the remaining three members could still form a robust tribe; however, a single member’s absence from a three-person tribe could have a greater impact. According to Patrick Laughlin et al., a group size of three people is necessary and sufficient to outperform the “best of an equivalent number of individuals on intellectual problems.” “Groups Perform Better Than the Best Individuals on Letters-to-Numbers Problems: Effects of Group Size,” *Journal of Personality and Social Psychology* 90, no. 4 (2006): 650. Second, grouping students into four tribes instead of five facilitated greater uniformity of initial course averages among tribes, thus providing each tribe with a more equitable chance of winning the game.

²⁸ The challenge worksheets and their corresponding answer keys are available as supplementary materials. Step-by-step instructions for finding the prime form of a pitch-class set (see Challenges 3, 5, and 7) were adapted from Straus, *Introduction to Post-Tonal Theory*, 58.

completed each challenge with the other members of their tribes.²⁹ A summary of the exercises included in each challenge appears in Appendix B, and a sample challenge appears in figure 1. To complete this challenge, students determined whether two given pitch-class sets were inversionally equivalent, inverted and transposed a given pitch-class set, and calculated the prime form of a given pitch-class set. A bonus question offered students the opportunity to earn extra credit by relating the previously calculated prime form (037) to the common musical structure it represents: namely, the major or minor triad. Prior to each challenge, I sent out an e-mail announcing the day of the challenge, informing students of its content, and directing them to resources that would help them prepare for the challenge.

Before beginning a challenge, students cleared their desks as they would for a typical quiz. They were permitted to talk freely with the other members of their tribes during the challenge, and I circulated the room to monitor progress and answer questions. Most challenges took twelve to fourteen minutes for students to complete. Each student turned in a copy of the challenge for an individual grade that became part of that student's quiz grade for the semester.³⁰ The scores of each member of a tribe were averaged together to form a tribe score. Relative

²⁹ Because students were new to set-theoretical analysis, the challenge exercises focused primarily on skills from the lower and middle rungs of Bloom's Taxonomy: remembering, understanding, and applying concepts. However, peer tutoring within tribes helped students to engage higher levels of learning through analysis and evaluation as they explained concepts and processes to their peers and monitored each other's progress during challenges. Benjamin S. Bloom et al., *Taxonomy of Educational Objectives: Cognitive Domain* (New York: McKay, 1956); Lorin W. Anderson and David R. Krathwohl, eds., *A Taxonomy for Learning, Teaching, and Assessment: A Revision of Bloom's Taxonomy of Educational Objectives* (New York: Longman, 2001).

Students' engagement with set theory was grounded in the analysis of musical scores. To illustrate the concept of transpositional equivalence, for example, the class examined an excerpt from the third of Webern's *Five Movements for String Quartet*, Op. 5. Students' early encounter with this movement was later followed by a guided homework analysis, in which students discussed alternative formal analyses, considered motivic development and texture, and calculated the prime form of trichords marked on the score. A subsequent analytical essay assignment directed students to compare Webern's now-familiar third movement with his fourth movement, which (incorporating Challenge 4) comprised the focus of a detailed in-class analysis. Finally, students demonstrated their understanding of set theory by composing and performing atonal melodies for their primary instruments.

³⁰ Students received three quiz grades during Set Theory Survivor, for a total of 3.33% of their course grade.

rankings of the four tribes throughout the unit were based on cumulative tribe scores, and the tribe that finished the unit with the highest cumulative score won the game.

Name:	Tribe:
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CHALLENGE 3

Inversion

- Determine whether the following normal form sets are inversionally equivalent. If yes, provide the index number.

Normal form sets	Inversionally equivalent?	Index number (T _N I)
[1,2,3,7] [10,2,3,4]		

- Perform the required inversion/transposition on the following normal form set.

Normal form set	Inversion/transposition
T ₁₁ I [1,3,6,9]	

Prime Form

Provide the prime form for the following normal form set.

- (Put set in normal form.)
- Transpose the set so that the first element is 0.
- Invert the original, normal-form set and repeat steps 1 and 2.
- Compare the results of step 2 and step 3; whichever is more packed to the left is prime form.

Normal form	Step two	Step three			Prime form
		Inversion of original	Normal form	Transposition	
[11,2,6]					

Bonus: What common musical structure is represented by the prime form of this set?

Figure 1. Challenge 3: Inversion and Prime Form.

Additional Links to Survivor

In addition to the central components of tribes and challenges, several game-like elements linked Set Theory Survivor to the television show *Survivor*. For example, I adapted the *Survivor* logo to fit Set Theory Survivor. The new logo frames tropical scenery and the phrase “Set Theory Survivor” with the ubiquitous clock face, or Krenek diagram, used to teach pitch-class set theory (see figure 2).



Figure 2. Logo for Set Theory Survivor.

This logo appeared for the first time in a brief opening credits video I designed and showed at the beginning of Set Theory Survivor. Inspired by the opening credits for *Survivor*, my video incorporates *Survivor* theme music and displays pictures of the game’s exotic location—namely, our classroom—and the four composers for whom the tribes were named.³¹ Its debut on the first day of Set Theory Survivor was greeted with laughter, applause, and requests for an encore. Students’ description of the video as “fun” persisted nearly a month later when I played the

³¹ Burks also incorporates adaptations of the *Survivor* logo and opening credits into his *Survivor Math* activities for college freshmen enrolled in remedial pre-calculus. “*Survivor Math*,” 68–69.

opening credits before announcing the winning tribe. During this screening, some students spontaneously cheered when pictures of their tribe's composer appeared. The Set Theory Survivor logo also appeared on the scoreboard slide that I updated and showed at the beginning of each class to keep students apprised of tribes' progress throughout the game. The slide shown in figure 3 displays the Set Theory Survivor logo against a background associated with the leading Bartók tribe by the color orange.³² Rankings for all four tribes appeared; in this example, the Bartók tribe occupied first place, the Schoenberg and Stravinsky tribes tied for second place, and the Berg tribe was in third place. Each scoreboard slide was accompanied by an audio recording of a brief composition by the leading tribe's namesake composer.



Figure 3. Sample scoreboard slide for Set Theory Survivor.

Two material elements of *Survivor*, buffs and survival supplies, had direct counterparts in Set Theory Survivor. On *Survivor*, the members of each tribe wear tube-shaped pieces of cloth called “buffs” that display their tribe colors and visually identify contestants with their tribes.

³² The respective tribe colors were purple (Schoenberg), orange (Bartók), green (Stravinsky), and gold (Berg). The final scoreboard slide replaced the phrase “Now leading...” with “And the winner is...”

Similarly, participants in Set Theory Survivor had cloth bandanas, which we called buffs, that they wore or tied to their backpacks. While *Survivor* supplies take the form of basic tools and limited food stores, the Set Theory Survivor supplies distributed to each tribe consisted of a folder containing staff paper and notebook paper for scratch-work during challenges, four dry-erase markers, and an eraser for work at the board.

The ultimate goal of *Survivor* contestants is to finish the game as Sole Survivor and thereby win one million dollars. Though much more modest in scope, the prospect of winning a prize also played an important role in Set Theory Survivor. While students' grades were not affected by the outcome of the game, the hope of earning a non-academic prize—a \$15 Starbucks® gift card for each member of the winning tribe—provided impetus for tribes to pull together and do their best. This reflected the social motivation approach to cooperative learning espoused by Slavin, and maintained the constructiveness of the competition by keeping the reward small and non-academic. Because the prize did not influence course grades, students could participate freely, and help their fellow tribe members without fear of their own grades being adversely affected by the outcome of the game; this structure reflected the social cohesion approach to cooperative learning set forth by Johnson and Johnson.

Results of Set Theory Survivor

Outcome of the Game

Harnessing the collective intelligence of their tribes, students performed very well on the challenge worksheets, though it should be stated that performance on homework assignments still reflected varying levels of achievement. Individual grades were averaged together to yield a tribe score for each challenge (see table 1), and cumulative tribe scores were tabulated throughout the game (see table 2).

Table 1. Tribe scores during Set Theory Survivor. Scores reflect a maximum score of 100% for each challenge, with the possibility of earning an additional 1% for the bonus question on Challenge 3.

Challenge #	Bartók	Berg	Schoenberg	Stravinsky
Challenge 1	100	100	98	99
Challenge 2	100	98	100	100
Challenge 3	101	100	101	100
Challenge 4	99	99	100	97
Challenge 5	100	100	100	97
Challenge 6	94	90	93	93
Challenge 7 (Individual)	88	88	96	80

Table 2. Cumulative tribe scores during Set Theory Survivor. The leading score for each challenge appears in bold.

Challenge #	Bartók	Berg	Schoenberg	Stravinsky
Challenge 1	100	100	98	99
Challenge 2	100	99	99	99.5
Challenge 3	100.3	99.3	99.7	99.7
Challenge 4	100	99.25	99.75	99
Challenge 5	100	99.4	99.8	98.6
Challenge 6	99	97.8	98.7	97.7
Challenge 7 (Individual)	97.4	96.4	98.3	95.4

Relative rankings of the four tribes throughout the unit were based on these cumulative scores, and the tribe that finished the unit with the highest cumulative score was declared the winner. While the Bartók and Berg tribes initially tied for first place, the Berg tribe lost ground after the second challenge, leaving the Bartók tribe to enjoy a winning streak of five more challenges. Not

until the final, individually completed challenge did the Bartók tribe give way to the Schoenberg tribe; after occupying second place for Challenges 3–6, the Schoenberg tribe earned the highest tribe score (by a decisive 8%) on Challenge 7, bypassing the long-leading Bartók tribe to win the game by a margin of 0.9%.

The Bartók tribe’s lengthy tenure as the leading tribe may be partially attributed to attendance: although members of this tribe occasionally missed a challenge, all of their absences were excused. Each of the other tribes accumulated both excused and unexcused absences during the unit. In order to encourage students to hold each other accountable for coming to class and engaging the material, each unexcused absence resulted in a 1% deduction from the tribe score for that challenge. Nonetheless, the cumulative scores of all four tribes remained extremely close throughout the competition—the first- and last-place cumulative scores for Challenges 2–4 were separated by only 1%. It was, as I told students on more than one occasion, “anybody’s game.” The prolonged success of the three-member Bartók tribe, and eventual victory of the four-member Schoenberg tribe, indicate that it is possible for tribes of different sizes to have similar chances of winning.

Student Learning

Students reported considerable learning during Set Theory Survivor. When responding to post-test Question 18 (“I learned a lot during the unit on set theory”), 30.8% of students strongly agreed, 61.5% agreed, and 7.7% slightly agreed.³³ As demonstrated by their pre-test and post-test responses to Questions 9–17, the self-perceived ability of students to perform specific set-theoretical operations and their level of comfort with set theory increased over the course of the unit. Student responses to these questions appear in table 3 (pre-test) and table 4 (post-test). In

³³ Few students had previous experience with set theory; only two students agreed or slightly agreed with pre-test Question 5 (“I have studied set theory before”).

order to facilitate visual comparisons among student responses, the results from tables 3 and 4 appear graphically in figures 4 and 5, respectively.

Table 3. Student pre-test responses to Likert-type questions addressing their experience with set theory and ability to perform set-theoretical operations. For questions numbered differently on pre-test and post-test, both numbers appear in the format pre-test number/post-test number. The symbol + denotes a question that appeared only on the pre-test questionnaire. Results indicate the percentage (rounded to the nearest 0.1%) of students who chose that response for the respective question; 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree. If two adjacent answers were circled, half the percentage was assigned to each answer.

Question	Text	1	2	3	4	5	6	7
5 ⁺	I have studied set theory before.	53.8	23.1	7.7	0	7.7	7.7	0
9	I can find the normal order of a pitch-class set.	38.5	38.5	15.4	7.7	0	0	0
10	I can find the prime form of a pitch-class set.	46.2	38.5	7.7	0	7.7	0	0
11	I can find the interval-class vector of a pitch-class set.	46.2	46.2	7.7	0	0	0	0
12	I can transpose a pitch-class set that is in normal order.	30.8	23.1	15.4	7.7	23.1	0	0
13	I can invert a pitch-class set that is in normal order.	30.8	30.8	7.7	7.7	23.1	0	0
14	I can invert and transpose a pitch-class set that is in normal order.	30.8	30.8	15.4	7.7	15.4	0	0
15	I can identify pitch classes that remain invariant under transposition.	30.8	53.8	7.7	7.7	0	0	0
16	I can identify pitch classes that remain invariant under inversion.	46.2	46.2	7.7	0	0	0	0
17/5	I am comfortable using set theory to analyze post-tonal music.	53.8	30.8	7.7	7.7	0	0	0

Table 4. Student post-test responses to Likert-type questions addressing their ability to perform set-theoretical operations. For questions numbered differently on pre-test and post-test, both numbers appear in the format post-test number/pre-test number. Results indicate the percentage (rounded to the nearest 0.1%) of students who chose that response for the respective question; 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree. If two adjacent answers were circled, half the percentage was assigned to each answer.

Question	Text	1	2	3	4	5	6	7
9	I can find the normal order of a pitch-class set.	0	0	0	0	0	15.4	84.6
10	I can find the prime form of a pitch-class set.	0	0	0	0	0	15.4	84.6
11	I can find the interval-class vector of a pitch-class set.	0	0	0	0	0	7.7	92.3
12	I can transpose a pitch-class set that is in normal order.	0	0	0	0	7.7	15.4	76.9
13	I can invert a pitch-class set that is in normal order.	0	0	0	0	0	23.1	76.9
14	I can invert and transpose a pitch-class set that is in normal order.	0	0	0	0	7.7	15.4	76.9
15	I can identify pitch classes that remain invariant under transposition.	0	0	0	7.7	7.7	38.5	46.2
16	I can identify pitch classes that remain invariant under inversion.	0	0	0	7.7	15.4	30.8	46.2
5/17	I am comfortable using set theory to analyze post-tonal music.	0	0	7.7	0	46.2	23.1	23.1

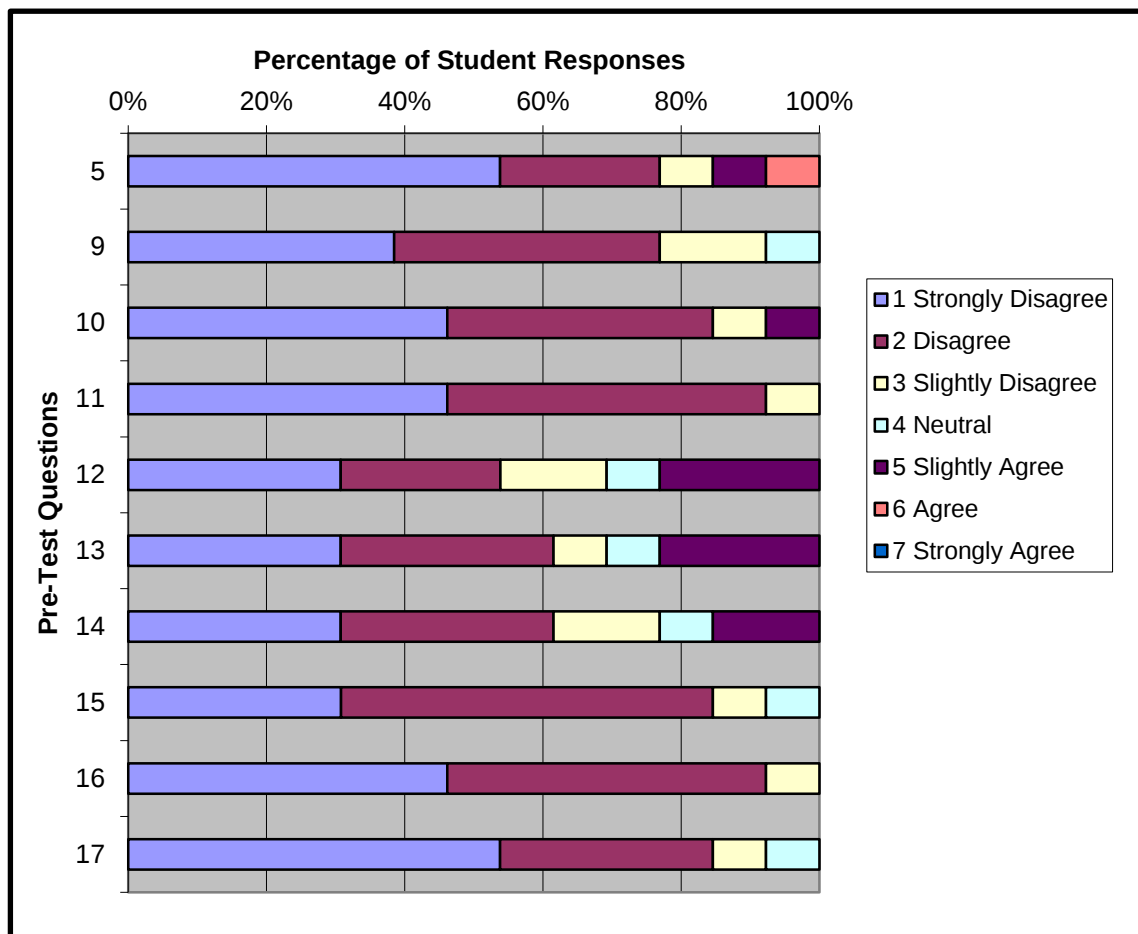


Figure 4. Student pre-test responses to Likert-type questions addressing their experience with set theory and ability to perform set-theoretical operations.

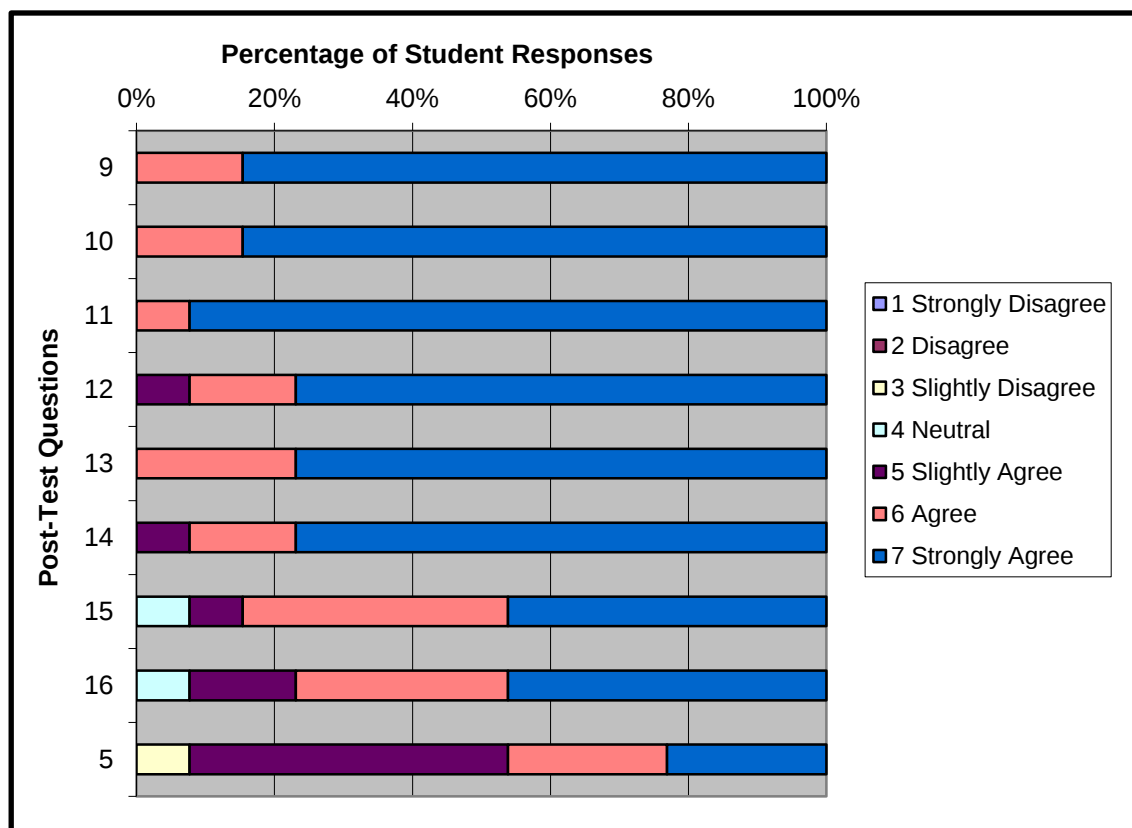


Figure 5. Student post-test responses to Likert-type questions addressing their ability to perform set-theoretical operations.

Figure 6 shows mean student responses to Likert-type questions that appeared on both questionnaires.³⁴ For questions numbered differently from pre-test to post-test, the graph refers to those questions by their pre-test numbers.³⁵ Data analysis consisted of paired t-tests with the Bonferroni correction for multiple tests ($\alpha = 0.05/16 = 0.003125$) and 95% confidence intervals. As seen in the graph in figure 6, the mean response of students increased from pre-test to post-

³⁴ Thirteen of the fifteen students participating in Set Theory Survivor completed the pre-test questionnaire; similarly, thirteen students completed the post-test questionnaire. However, only twelve students completed both pre-test and post-test questionnaires. While the percentages shown in tables 3 and 4 and figures 4 and 5 reflect the responses of all thirteen students who completed the respective questionnaires, the graph in figure 6 includes only the responses of the twelve students who completed both questionnaires.

³⁵ For instance, Q17 includes pre-test Question 17 and post-test Question 5; Q18 includes pre-test Question 18 and post-test Question 22; and Q19 includes pre-test Question 19 and post-test Question 23. All other questions shown on this graph were numbered identically on pre-test and post-test.

test by at least 4.2 points on a 7-point scale (in several instances, from Disagree to Agree) on every question pertaining to students' ability to perform specific set-theoretical operations (Questions 9–16). The overall growth of students in capability and confidence is reflected by the marked increase from pre-test to post-test in mean responses to Question 17 (“I am comfortable using set theory to analyze post-tonal music”). The mean differences in student responses to Questions 9–17 were statistically significant; as seen in figure 6, the confidence intervals associated with the mean pre-test and post-test responses to these questions do not overlap.³⁶

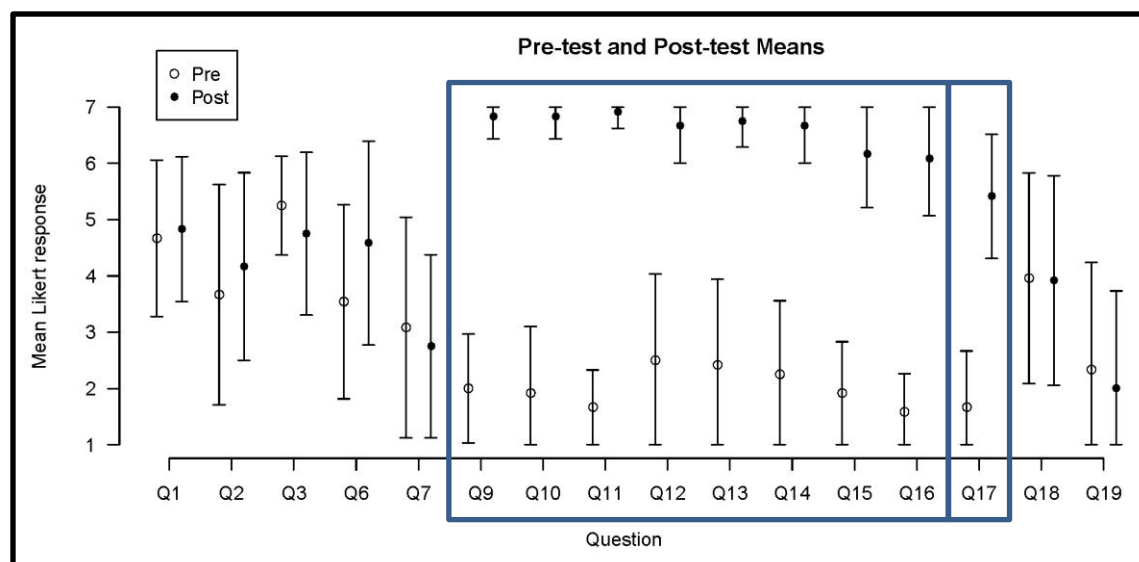


Figure 6. Pre-test and post-test mean student responses. Open circles represent pre-test means; filled circles denote post-test means. Each mean is accompanied by a 95% confidence interval.

³⁶ There was a slight (although not statistically significant) increase in mean student responses to Question 6 (“I appreciate the underlying structure of post-tonal music”). Students’ enjoyment of listening to post-tonal music, as measured by their responses to Question 7 (“I like to listen to post-tonal music”), did not increase; however, the qualitative responses of students to Question 4 (“What do you like the most about post-tonal music?”) reveal that all thirteen of the students who completed the post-test questionnaire (versus eleven of thirteen students who completed the pre-test) were able to identify some aspect of post-tonal music that they liked. No statistically significant differences emerged in mean student responses to questions addressing students’ learning and working preferences (Questions 1–3) or their engagement with the television show *Survivor* (Questions 18–19).

Comments during the group discussion at the end of the unit highlighted the importance of daily challenges in regard to student learning. One student appreciated the “constant reinforcement” provided by daily challenges. Another explained that the daily challenges “made me go home and actually look at my notes and make sure I knew [the material] before I came to class.” The comment of a third student summed up the general consensus; when asked what she would keep the same if playing Set Theory Survivor again, she responded, “The daily challenge[s]. They were annoying, but they helped.” When reflecting on Set Theory Survivor, a music education major found it helpful to see there is more than one way to teach; Set Theory Survivor inspired her to consider “more interesting ways to share information with kids.” Thus, the impact of Set Theory Survivor on student learning has the potential to go beyond the learning of participants themselves to influence the learning of students who will someday be taught by participants in Set Theory Survivor.

Peer Tutoring and Student Responsibility

Peer tutoring was integral to Set Theory Survivor. While working in their tribes, students regularly asked each other questions, provided explanations, and compared answers to practice worksheets and challenges. Instead of the quiet, tense atmosphere associated with traditional quizzes, challenges sparked lively conversations and camaraderie among students. Students explicitly asked their fellow tribe members if they understood the skills required for the challenge at hand and supplied explanations when needed—sometimes rising from their desks and moving to stand or sit by different members of their tribes to facilitate giving or receiving these explanations. Explanations came from more than one member of each tribe, and both higher- and lower-achieving students received help from their fellow tribe members. By the third

challenge, tribes functioned with relative independence; I remained available to answer questions, but the tribes usually had matters well in hand.

Students commented favorably on working with their peers throughout the learning process. One student identified an increasingly open dialogue resulting from Set Theory Survivor, while another student described the game as a “bonding experience” that formed connections within the class. This student explained that she had never spoken with one of her fellow tribe members prior to Set Theory Survivor; however, their work together in class now extended beyond the classroom to authorized collaboration on homework assignments.

Many students exhibited a sense of responsibility toward the other members of their tribes. In addition to attending class consistently—even on the Friday before Spring Break—students expressed concern for their fellow tribe members when absences were unavoidable. During the group discussion, one student mentioned feeling pressure to “do well for my team.”³⁷ Constructive peer pressure also motivated a student who was frequently absent before Set Theory Survivor to attend class much more regularly. A student who received a low grade on the individually completed Challenge 7 apologized to fellow tribe members for bringing down their tribe score. Another student, who openly displayed her tribe spirit by keeping her buff tied to her backpack on days when we did not have class, said that she was very proud of her tribe.³⁸

Perspectives on Set Theory Survivor

Student responses to Likert-type post-test questions illuminated their perspectives on Set Theory Survivor (see table 5 and figure 7). As previously discussed, students reported

³⁷ This student still described Set Theory Survivor as enjoyable.

³⁸ This student and at least one other student kept their buffs tied to their backpacks more than three weeks after the conclusion of Set Theory Survivor (i.e., until the end of the semester). A third student had his buff tied to his instrument case three weeks after the conclusion of Set Theory Survivor. Each of these three students represented a different tribe.

considerable learning during Set Theory Survivor—all students who completed the post-test questionnaire agreed to some extent with Question 18. Similarly, these students unanimously believed “[t]he ‘Theory Survivor’ format made the unit on set theory interesting” (Question 24).

Table 5. Student responses to Likert-type post-test questions addressing their perspectives on Set Theory Survivor. The results indicate the percentage (rounded to the nearest 0.1%) of students who chose that response for the respective question; 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree. If two adjacent answers were circled, half the percentage was assigned to each answer.

Question	Text	1	2	3	4	5	6	7
18	I learned a lot during the unit on set theory.	0	0	0	0	7.7	61.5	30.8
19	The “Theory Survivor” format made the unit on set theory challenging.	15.4	15.4	7.7	15.4	0	38.5	7.7
20	The “Theory Survivor” format made the unit on set theory enjoyable.	0	0	0	7.7	7.7	53.8	30.8
24	The “Theory Survivor” format made the unit on set theory interesting.	0	0	0	0	38.5	23.1	38.5

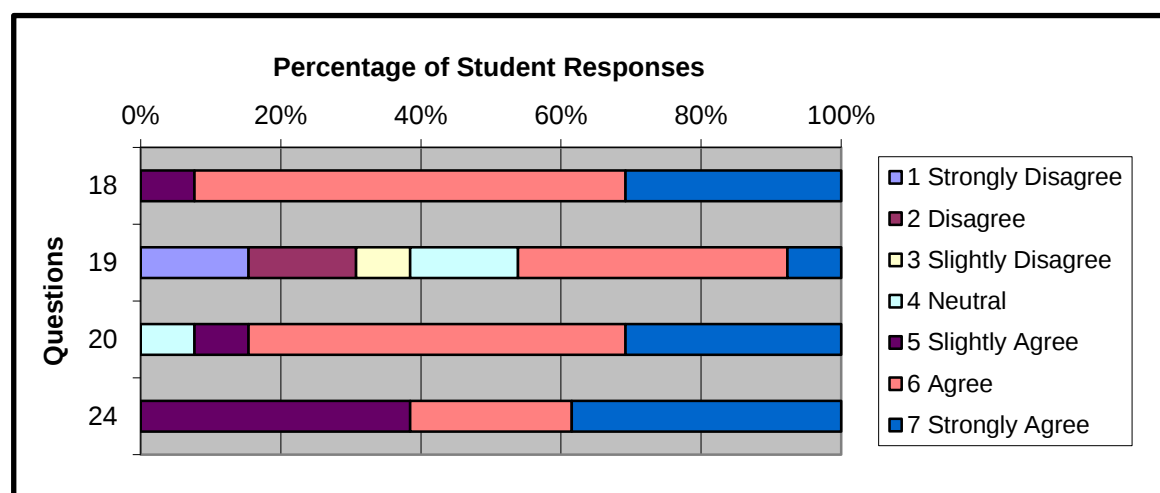


Figure 7. Student responses to Likert-type post-test questions addressing their perspectives on Set Theory Survivor.

An overwhelming majority of students (92.3%) believed the game-like format of the unit was enjoyable, as evidenced by their responses to Question 20. Students' enjoyment of Set Theory Survivor was further reflected in their additional comments on the post-test questionnaire. One student wrote, "It was fun! I liked it a lot," while another student remarked, "Nice idea with how the unit was set up." A third student described Set Theory Survivor as "fun" and "enjoyable" during the group discussion at the end of the unit. One student also commented, "I really enjoyed the Survivor experiment!" on the end-of-semester course evaluation.

The breadth of student responses to Question 19 ("The 'Theory Survivor' format made the unit on set theory challenging") may reflect different perspectives on what constitutes a challenge. Working together with one's peers reduced the pressure of retaining concepts and applying skills individually, but the positive interdependence built into the tribes made each student partially responsible for the success of other tribe members. One student made the latter perspective explicit by writing the following comment beside Question 19: "[Y]ou had to work hard for you and your group."

When asked during the group discussion what they would keep the same and what they would change about Set Theory Survivor, students expressed their desire to keep the primary elements of the game—the daily challenges, competition, and tribes—in place. In order to make challenges more exciting, they suggested physical games, such as a race to write something on the board. Finally, students recommended giving tribes the ability to vote members out or rearranging tribes through a merge in order to minimize the impact of tribe members with less consistent attendance. While the proposed challenge modification would be relatively simple to implement, it would be difficult to modify tribal membership during the game without devaluing

the contributions of lower-achieving students or undermining the developing cohesion of each tribe.

As an instructor, I was satisfied with how Set Theory Survivor unfolded in the classroom. The learning of both higher- and lower-achieving students was enhanced by working with their peers and explaining concepts to each other. Students enjoyed the process of learning about set theory while working with their fellow tribe members toward the goal of winning a non-academic prize, and they remained actively engaged with the course material throughout the unit. The engagement of students reflected both the motivated self-interest identified by Slavin and the group cohesion identified by Johnson and Johnson as effective forces of cooperative learning. Set Theory Survivor also proved invaluable in boosting energy levels during the mid-semester doldrums. While my workload increased due to preparing and grading a challenge for nearly every class period, I was pleased with the responsibility and camaraderie I saw among my students, and I enjoyed teaching this challenging unit via the framework of a pedagogical game. I highly recommend Set Theory Survivor to other music theory instructors.

Reflections and Further Considerations

Fresh from multiple semesters of tonal theory, undergraduate music students bring tonal ears and expectations to their study of atonal music. When confronted with a musical world in which tonal expectations are frequently thwarted, students may experience confusion or frustration, which may, in turn, hinder them from fully embracing the rich analytical potential of pitch-class set theory. Therefore, one of the greatest challenges for undergraduate students encountering set theory for the first time is the unfamiliarity of the entire enterprise—a body of music whose departure from tonality necessitates a new collection of analytical tools. Other challenges are inherent to set-theoretical analysis. For example, enharmonic and octave

equivalence enable analytical connections among seemingly diverse elements of the musical surface; however, their reductive nature also obscures potentially important facets of pitch and register. Accordingly, the most effective applications of set theory make full use of the powerful analytical tools afforded by enharmonic and octave equivalence while still considering noteworthy elements of pitch space.

In spite of these challenges, undergraduate music students can benefit both directly and indirectly from engaging set theory in the core curriculum. The most obvious direct benefit concerns students who choose to specialize in music theory or composition and should therefore be prepared to engage set-theoretical analysis and composition in their own work and that of their colleagues. Students who become performers, conductors, and teachers of twentieth-century atonal music also benefit directly from engaging this analytical system: their initial study of pitch-class set theory lays the foundation for lifelong learning as they read about, perform, and teach this repertoire. Conversely, students' exposure to the repertoire and concepts associated with set theory may pique their interest and inspire them to engage this body of music more deeply in the future. Straddling the boundary between direct and indirect benefits, exposure to set theory affords students a deeper understanding of compositional aspects of a seminal period in music history. This insider's perspective, as it were, can help students better apprehend the reactions and eventual syntheses that shaped the face of art music in the early twentieth century and beyond. While this knowledge may most directly benefit those students who specialize in musicology, it also forms an essential component of a thorough education for musicians of all specializations.

Important indirect benefits may also accrue to students through their study of set theory. As previously noted by Silberman, atonal music is a "foreign language" to many undergraduate

music students.³⁹ While this metaphor neatly encapsulates the initial challenge of introducing students to atonal repertoire, it need not be a negative one. The experience of learning a second language is widely acknowledged as a beneficial means of enhancing one's communication skills while fostering an awareness of, and appreciation for, diversity among cultures. Many students seek out such transformative experiences by studying abroad as part of their college education. Why should such opportunities for intellectual and personal growth not also be afforded to undergraduate music students? Indeed, twentieth-century atonal music provides an ideal venue for a virtual "study abroad" experience: while the vast majority of students have grown up listening to tonal music in various classical or popular genres, fewer students enter undergraduate music programs with extensive—or, in some cases, any—prior experience listening to or performing atonal music. Thus, students have the opportunity to expand their horizons from early encounters with this repertoire to a working knowledge of its basic structural properties—to start from the outside and find a way in. Instructors play an important part in this journey of discovery as they nurture the curiosity of students, model disciplinary ways of thinking about music like a theorist, and help cultivate students' music-analytical acumen.

Other indirect benefits of studying pitch-class set theory extend beyond the field of music. Jim Grossman identifies four skill areas—presentation skills, collaboration skills, basic quantitative skills, and intellectual self-confidence—that contribute to professional success both inside and outside the academy.⁴⁰ Aspects of all four areas appear in *Set Theory Survivor*. Through peer tutoring, students simultaneously practice collaboration and strengthen their

³⁹ Silberman, "Post-Tonal Improvisation," [1].

⁴⁰ Jim Grossman, "Graduate Education and Career Horizons in the Humanities" (lecture for the Graduate School, The Ohio State University, Columbus, OH, February 17, 2015). While Grossman addressed his lecture to graduate students, the same skills are also important for undergraduate music students who may work in a variety of capacities (performing, teaching, etc.) throughout their careers.

presentation skills as they learn to explain concepts and analytical procedures concisely in the supportive environment of their tribe. The computational aspect of Set Theory Survivor refreshes students' knowledge of basic quantitative skills and reinforces the importance of accurately following the proper sequence of steps (e.g., invert first, then transpose) when solving analytical problems. Finally, the milieu into which students without previous exposure to atonal music are thrust is precisely the type of setting that spurs students along the road to intellectual self-confidence as they master new tools for music analysis while confronting an unfamiliar repertoire.⁴¹

The success of Set Theory Survivor rests on a tripartite synthesis of cooperative learning, constructive intergroup competition, and a pedagogical game. All three components are vital to the effectiveness of Set Theory Survivor. Cooperative learning provides students with the camaraderie of fellow tribe members who share explanations, strategies, and social support as they work toward the common goal of understanding set theory. Through constructive intergroup competition, the prospect of earning the highest cumulative tribe score—and thereby winning a prize—prompts students to put forth their best effort and to facilitate the efforts of their peers. Finally, the pedagogical game renders the unit of study more enjoyable for students by linking educational practice to popular culture. The results of the study confirm that Set Theory Survivor presents an effective approach to a difficult subject and provides a creative tool to enhance the pedagogy of pitch-class set theory.

⁴¹ Grossman describes intellectual self-confidence as the ability to say, "I don't know anything about that. Give me twenty-four hours, and I'll figure it out." The high concentration of new analytical techniques associated with set theory provides many opportunities for students, assisted by their instructors, to develop this type of confidence.

Bibliography

- Anderson, Lorin W., and David R. Krathwohl, eds. *A Taxonomy for Learning, Teaching, and Assessment: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman, 2001.
- Atkins, Rebecca, and Michael Murray. "Revisiting Theory Camp: Improving Student Success in Freshman Theory." *Music Theory Pedagogy Online* 1 (2013): 1–15.
- Berry, Whitney. "Beyond Survival: Using Games to Thrive in Lecture." In *Exploring Learning & Teaching in Higher Education*, edited by Mang Li and Yong Zhao, 45–68. Berlin: Springer, 2015.
- . "Surviving Lecture: A Pedagogical Alternative." *College Teaching* 56, no. 3 (Summer 2008): 149–53.
- Bloom, Benjamin S., Max D. Englehart, Edward J. Furst, and David R. Krathwohl. *Taxonomy of Educational Objectives: Cognitive Domain*. New York: McKay, 1956.
- Burks, Robert. "Survivor Math: Using Pop Culture to Enhance Learning Mathematics." *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies* 21, no. 1 (January 2011): 62–72.
- Faust, Jennifer L., and Donald R. Paulson. "Active Learning in the College Classroom." *Journal on Excellence in College Teaching* 9, no. 2 (1998): 3–24.
- Gillespie, Jeff. "Welcome to Theory Camp! More Than Simple Remediation." *Journal of Music Theory Pedagogy* 14 (2000): 47–62.
- Gingerich, Lora L. "Pitch-Class Poker." *Journal of Music Theory Pedagogy* 5, no. 2 (Fall 1991): 161–78.
- Grossman, Jim. "Graduate Education and Career Horizons in the Humanities." Lecture for the Graduate School, The Ohio State University, Columbus, OH, February 2015.
- Harter, Courtenay L. "Bridging Common Practice and the Twentieth Century: Cadences in Prokofiev's Piano Sonatas." *Journal of Music Theory Pedagogy* 23 (2009): 57–77.
- Howard, Mary G., Heidi L. Collins, and Stephen E. DiCarlo. "'Survivor' Torches 'Who Wants to Be a Physician?' in the Educational Games Ratings War." *Advances in Physiology Education* 26 (2002): 30–36.
- Johnson, David W., and Roger T. Johnson. *Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning*. 5th ed. Boston: Allyn and Bacon, 1999.

- Kleppinger, Stanley V. "Strategies for Introducing Pitch-Class Set Theory in the Undergraduate Classroom." *Journal of Music Theory Pedagogy* 24 (2010): 131–56.
- Kostka, Stefan. *Materials and Techniques of Post-Tonal Music*. 4th ed. Upper Saddle River, NJ: Pearson, 2011.
- Laughlin, Patrick R., Erin C. Hatch, Jonathan S. Silver, and Lee Boh. "Groups Perform Better Than the Best Individuals on Letters-to-Numbers Problems: Effects of Group Size." *Journal of Personality and Social Psychology* 90, no. 4 (2006): 644–51.
- Lewin, David. *Generalized Musical Intervals and Transformations*. New York: Oxford University Press, 2011.
- Mummalaneni, Venkatapparao, and Soumya Sivakumar. "Effectiveness of a Board Game in Fostering a Customer Relationship Orientation Among Business Students." *Journal of Relationship Marketing* 7, no. 3 (2008): 257–73.
- Pence, Dan. "'I'll Take Ideology for \$200, Alex': Using the Game Show *Jeopardy* to Facilitate Sociological and Critical Thinking." *Teaching Sociology* 37 (April 2009): 171–76.
- Ripley, Angela N. "Surviving Set Theory: A Pedagogical Game and Cooperative Learning Approach to Undergraduate Post-Tonal Music Theory." Ph.D. diss., The Ohio State University, 2015.
- Robyn, Elisa. "Creating Tribes." *College Teaching* 48, no. 2 (Spring 2000): 65–68.
- Roig-Francolí, Miguel. *Understanding Post-Tonal Music*. New York: McGraw Hill, 2008.
- Root, Jena. "Stravinsky's 'Spring Rounds': Primer for a Twentieth-Century Musical Aesthetic." *Journal of Music Theory Pedagogy* 24 (2010): 13–35.
- Silberman, Peter. "Post-Tonal Improvisation in the Aural Skills Classroom." *Music Theory Online* 9, no. 2 (July 2003): [1]–[41].
- Slavin, Robert E. "Classroom Applications of Cooperative Learning." In *APA Educational Psychology Handbook*, vol. 3: Application to Learning and Teaching, edited by Karen R. Harris, Steve Graham, and Tim Urdan, 359–78. Washington, D.C.: American Psychological Association, 2012.
- . *Cooperative Learning*. Research on Teaching Monograph Series. New York: Longman, 1983.
- Straus, Joseph N. *Introduction to Post-Tonal Theory*. 3rd ed. Upper Saddle River, NJ: Pearson, 2005.
- . "A Primer for Atonal Set Theory." *College Music Symposium* 31 (1991): 1–26.

Waren, Warren. "Using *Monopoly* to Introduce Concepts of Race and Ethnic Relations." *The Journal of Effective Teaching* 11, no. 1 (2011): 28–35.

Appendix A: Pre-test and Post-test Questions and Motivations

Likert-type questions and motivations from pre-test and post-test questionnaires. Unless otherwise indicated, the questions were numbered identically on pre-test and post-test. For questions numbered differently on pre-test and post-test, both numbers are shown in the format pre-test number/post-test number. The symbol + denotes a question that appeared only on the pre-test questionnaire; the symbol * denotes a question that appeared only on the post-test questionnaire.

QUESTION		MOTIVATION
Learning and Working Preferences		
1	I like to learn about new techniques for analysis.	Investigated students' openness to learning new analytical techniques. Assessed students' preferences for learning individually or together in light of the cooperative-learning focus of Set Theory Survivor.
2	I prefer to complete assignments by myself.	
3	I prefer to complete assignments with other people.	
Attitudes toward Post-Tonal Music		
6	I appreciate the underlying structure of post-tonal music.	Addressed student appreciation of structural elements of post-tonal music on an academic (not aesthetic) level. Students could potentially "appreciate" the structure (i.e., recognize that it exists and respect it) without yet being able to "understand" it fully. Explored aesthetic response of students to post-tonal music.
7	I like to listen to post-tonal music.	
Experience with Set Theory and Ability to Perform Set-Theoretical Operations		
5 ⁺	I have studied set theory before.	Measured students' prior experience (if any) with set-theoretical analysis. Probed the self-reported ability of students to perform specific set-theoretical operations. Operations were listed separately—avoiding combining skills learned early in the unit with skills learned late in the unit—in order to facilitate a nuanced understanding of student learning.
9	I can find the normal order of a pitch-class set.	
10	I can find the prime form of a pitch-class set.	
11	I can find the interval-class vector of a pitch-class set.	
12	I can transpose a pitch-class set that is in normal order.	
13	I can invert a pitch-class set that is in normal order.	
14	I can invert and transpose a pitch-class set that is in normal order.	
15	I can identify pitch classes that remain invariant under transposition.	
16	I can identify pitch classes that remain invariant under inversion.	
17/5	I am comfortable using set theory to analyze post-tonal music.	Assessed the overall self-reported competence of students with pitch-class set theory.
Engagement with Television Show Survivor		
18/22	I enjoy watching the television show Survivor.	Explored whether students were fans of Survivor in case engagement with Survivor influenced their perceptions of Set Theory Survivor, or vice versa.
19/23	I watch the television show Survivor regularly.	
Perspectives on Set Theory Survivor		
18*	I learned a lot during the unit on set theory.	Examined student perceptions of how Set Theory Survivor contributed to students' learning and affective experience during the unit.
19*	The "Theory Survivor" format made the unit on set theory challenging.	
20*	The "Theory Survivor" format made the unit on set theory enjoyable.	
24*	The "Theory Survivor" format made the unit on set theory interesting.	

Open-ended questions and motivations from pre-test and post-test questionnaires. Questions were numbered identically on both pre-test and post-test. The symbol * denotes a question that appeared only on the post-test questionnaire.

QUESTION		MOTIVATION
Attitudes toward Post-Tonal Music		
4	What do you like the most about post-tonal music?	Explored student attitudes toward post-tonal music. Parallel wording was used for both questions in order to avoid bias.
8	What do you dislike the most about post-tonal music?	
Attitudes toward Set Theory Unit		
17*	What aspect of the unit on set theory did you most like?	Explored student attitudes toward course unit framed by Set Theory Survivor. Parallel wording was used for both questions in order to avoid bias.
21*	What aspect of the unit on set theory did you most dislike?	
Additional Comments		
N/A	Please write any additional comments that you have.	This unnumbered question appeared at the very end of each questionnaire and offered students an opportunity to share additional feedback.

Appendix B: Summary of Challenges⁴²

Challenge	Tasks
Challenge 1	▪ Convert pitch names from letters to integers ▪ Perform calculations with modulo 12 arithmetic ▪ Identify ordered and unordered pitch-class intervals ▪ Calculate the normal form of pitch-class sets
Challenge 2	▪ Determine transpositional equivalence of pitch-class sets ▪ Transpose a pitch-class set
Challenge 3	▪ Determine inversional equivalence of pitch-class sets ▪ Invert and transpose a pitch-class set ▪ Find the prime form of a pitch-class set
Challenge 4 ⁴³	▪ Convert a notated septachord to integer notation ▪ Find the normal form of this pitch-class set ▪ Find the prime form of this pitch-class set ▪ Calculate the interval-class vector for this pitch-class set
Challenge 5	▪ Find the prime form of a pitch-class set ▪ Determine transpositional equivalence of pitch-class sets ▪ Invert and transpose a pitch-class set
Challenge 6 (Requires List of Set Classes)	▪ Find pitch classes that remain invariant under transposition (consult the List of Set Classes) ▪ Determine which transpositions produce a specific number of invariant pitch classes ▪ Complete a summation square for a pitch-class set and give the index vector ▪ Determine which inversions of the pitch-class set produce specific numbers of invariant pitch classes
Reward Challenge (Ungraded)	▪ Match terms with their visual representations ▪ Complete review exercises at the board
Challenge 7 (Individual)	▪ Transpose a pitch-class set ▪ Determine inversional equivalence of pitch-class sets ▪ Find the prime form of a pitch-class set ▪ Given a pitch-class set and its interval-class vector, determine which transpositions produce a specific number of invariant pitch classes ▪ Complete a summation square for a pitch-class set and give the index vector

⁴² The challenges and their corresponding answer keys are available as supplementary materials.

⁴³ This challenge was part of a class-long interactive analysis engaging aspects of form, motive, pitch, texture, and dynamics in the fourth of Webern's *Five Movements for String Quartet*, Op. 5. The septachord provided for this challenge—David Lewin's FLYAWAY motive, see *Generalized Musical Intervals and Transformations* (New York: Oxford University Press, 2011): 188–89—plays a prominent role in demarcating the three sections of this movement.