Interdisciplinary lightning: a model for networking advanced undergraduate courses

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Abstract

In undergraduate education, one grapples with the problem of achieving a good balance between breadth and depth, particularly in the framework of interdisciplinary interactions. Here, a model is proposed that includes interdisciplinary interaction while working toward depth in the discipline. A pair of courses, particularly from starkly different fields of study, comes together for an extremely short, collaborative joint event in which students apply advanced, specialized material learned during the course of the term. Pairs of courses rotate freely term by term, so that when the original pair reunites, each has been enriched by a different sequence of interdisciplinary connections. The networking scheme is probed in terms of small world modeling concepts and other analogs. The scheme allows for high mobility, minimizes constraints on participation, avoids mixed-prerequisite problems, can be implemented with existing courses, and can catalyze joint research. An example of such a collaboration between the Electrical and Computer Engineering and Music Departments at Union College will be presented.

Introduction

Striking a balance between depth and breadth is essential in undergraduate education[1,2]. The development of a palette of models for interdisciplinary interaction which lie at different points on the spectrum from depth to breadth enables different routes to such a balance to be pursued, as appropriate for the situation[3-6]. Here, we seek to add a point on the spectrum that increases depth of preparation in a core discipline and prepares students to communicate with members of other disciplines. Giving students the strongest possible foundation in the basic tools of some discipline is one element of striking a good balance between depth and breadth.

Many approaches depend on an extended interaction between two or more disciplines. Provided that one exceeds the threshold for startup, longer interaction lengths produce significant increase in output. The interdisciplinary boundary brings the advantage of a high growth rate, which is extremely attractive.

Yet, at the same time, these approaches limit participation. For example, the practicalities involved in developing a new course or making extensive changes to an existing course are prohibitive for many faculty. Courses co-taught by several faculty require significant commitment, organization and a finely-tuned level of synchronization, and faculty can be juggling heavy course overloads in order to participate. In addition, it is already difficult to fit the material essential for the major within four years, and reaching higher levels of understanding, such as described by Bloom's taxonomy[7], requires time. Thus, while interest in participation in interdisciplinary collaborations might exist, in many cases, the practical threshold for participation is simply too high.

Key assumption

The following assumption is the crux of the approach. Given two disconnected or discontinuous disciplines, each having depth, it is assumed possible for a very short interaction to produce a discrete jump in progress. That is, a very short interaction can be arranged which has a result metaphorically similar to integration over a delta function.

Proposed approach

The proposed model has three principal components.

1) A short interaction occurs between a pair of courses in which students from each course apply and reinforce their own course material
2) The interaction, while short, is designed to benefit everyone involved
3) Free rotation of pairs of courses occurs, term by term

The scheme functions in the backdrop and emphasizes freedom and flexibility, acknowledging demands on time and material coverage. Perhaps some rotations will have large periods and diameters; others may stop quickly, as best serves the primary purpose of the courses. Some interactions may remain part of courses permanently. Others may simply persist in memory, so that as pairs of courses rotate, communication routes between faculty in remote disciplines increase in number, and when the original pair reunites, each brings a different set of connections and experiences back to the table. Each course remains essentially independent, minimizing synchronization requirements. The interdisciplinary lightning, while short, can trigger the start-up of lengthier combined efforts such as joint senior capstone projects, joint faculty research projects, and so forth.

Examples:

This model has been implemented over the course of two years, during which three pairs of courses have crossed paths. A brief description of each course follows:

ECE370 "Engineering Acoustics." This is a new junior/senior level course in electrical engineering which gives students practice synthesizing material from the core curriculum, including circuit theory, signal processing, digital signal processing and electromagnetics using exercises involving audio and acoustics[8]. The course also offers opportunities to explore the use of sound to reinforce concepts in electrical engineering.

AMU215 “Music in the Twentieth Century” explores styles and trends in the music of the last century. Students study scores, write short analytical and research papers, and compose original works in the style of various modern composers.

AMU061 “From Beethoven to Bernstein.” This is a music appreciation course. Students learn about the composers' lives and learn to recognize stylistic aspects of their music through guided listening exercises. Some of the genres included are symphony, opera, art song, piano sonata, string quartet, and electronic music.

AMU230 “Vocal Chamber Workshop.” This course is about the art of singing in a small group, a type of chamber singers. Most of the repertoire comes from the Medieval, Renaissance, and Baroque eras. Each student learns to hold his or her own part against others in contrapuntal music. Some time is also given to developing sightreading skills.

Example 1. Direct connection

The following short, joint event connecting AMU230 and ECE370 illustrates active interaction between students in the two classes. The electrical engineering students started with recordings of the Chamber Singers made under acoustically dry conditions. They convolved the music signal with their own measurements of the impulse response of the College’s Memorial Chapel in order to simulate the auditorium’s reverberation contribution. They then made a direct recording of the same piece during a performance by the Chamber Singers in Memorial Chapel. After the concert, while munching on cookies and other refreshments, the engineering students explained their project, presented the Chamber Singers with the actual recording and the processed signal, and asked them to guess which one was real.

In this exercise, students from each class applied material learned during the term. The exercise performed by the electrical engineering students involved signal processing (convolution, impulse response) and auditorium acoustics, and the students worked actively in the midst of an exquisite performance by the Chamber Singers. The exercise also required the engineering students to practice communicating their project to peers outside their field, a critical and often underdeveloped skill. Students belonging to the Chamber Singers came to some understanding of the mechanics by which the engineering students processed the recorded material. The Chamber Singers also learned to articulate the technical differences between the two audio recordings in terms that the engineering students could understand. Moving to the broader point of view, the encouragement of an appreciation for the arts is consistent with the spirit of an engineering education within a liberal arts institution.

Example 2. Connection via intermediate node

In this example, the students from AMU032 and ECE370 came together for a short, joint event given by a guest mentor. Bradford Gowen, from School of Music at the University of Maryland at College Park, gave a two-part lecture-demonstration entitled, “Many Out of One – the Voices of the Piano” followed by a gripping, formal recital of *avant garde* music in Memorial Chapel. These events were also open to the general campus community. From the point of view of the electrical engineering students, who had worked out detailed examples of the Fourier decomposition of plucked and struck strings, hearing the changes in sound corresponding to different boundary/initial conditions added a new dimension to this kind of analysis. From the point of view of the 20^{th}-century music class, Bradford Gowen's performance was invaluable in its presentation of important twentieth-century musical landmarks in a live setting. His pre-performance remarks and answers to student questions allowed the students to connect more directly with the music while reinforcing terms and concepts introduced in the classroom.

In this example, the higher degree of separation between the classes did not at all impede the process. This example illustrates the simultaneous utilization of two completely different facets of the same event. The shared progress became possible in the presence of the intermediate node (the guest mentor.)

Example 3. Connection via multiple networking platforms.

In a short, joint event connecting AMU061 and ECE370, a guest lecturer with depth of expertise in the two distinct areas of specialization was invited to Union. Ed Kottick, Prof. Emeritus from the University of Iowa, gave two back-to-back lectures, entitled "Wire, Wood, Air and Ear: How the Harpsichord Makes its Sound" and "Gods and Mortals, Monkeys and Dolphins: The Exotic World of Early Keyboard Instruments." In one of the most special sparks which occurred during the course of this event, a group of about ten artisan builders (harpsichord, fortepiano and organ) and tuners from the area connected with one another upon our invitation to welcome the guest with dinner. The artisans joined the classes for the talks the next day. We were struck by the interchanges which took place among the artisan builders and were pleasantly surprised to find that we brought together builders who had known one another for decades as well as helped to establish new relationships.

In ECE370, the electrical engineering students performed a follow-up project related to Ed Kottick's lecture on harpsichord physics and construction. They divided up a set of signals covering the full range of the harpsichord keyboard, analyzed the measurements to obtain the relative strengths of the Fourier coefficients, and computed the Fourier coefficients from the analytic solution of the boundary value problem for a plucked string. One of the harpsichord experts from the area[9] also suggested a similar research project involving his reconstructed, antique instrument.

In this example, the short joint event exposed students to a mentor having depth of expertise in two areas. The degree of separation between the two classes was also high compared with Example 1. However, a surprising number of sub-networks, both internal and external to the College, connected with each other as students, faculty, the guest speaker, the instrument builders and tuners, and other members of the general campus community came together and interacted through the event. The connections spontaneously extended beyond what we originally planned.

Follow-up.

The model has been robust to unexpected surprises: a sudden scheduling change of one of the courses from Spring to Winter term and a sabbatical on the part of one of the collaborators. The interactions have sparked discussions of a possible longer-term collaboration between the two departments involving two recently donated harpsichords of the same model but under different physical condition.

Interdisciplinary networks on campus and the small world phenomenon[10]

The study of complex networks and application to diverse systems in nature is an area of intense research[11-16]. Reviews organizing the explosion of recent work in the field can be found in references 17 and 18, including the investigations of social systems and networks related to the brain. The way in which clustering and the distribution of local *versus* long range connections contributes to the characteristics of the overall network is a particular focus of the research. In academia, strong clustering appears in the form of academic departments, while fewer connections exist among the departments, especially between pairs in the hard sciences and the humanities. Furthermore, faculty can be linked through short chains of other faculty. These features are consistent with descriptions of small world networks[11,19]. The scientific co-authorship network, a collaboration network offering the advantage of large, quantifiable data sets for analysis, has been systematically studied in this context[20-32]. However, this social network can also be cross-sectioned in other ways, such as the network of interdisciplinary connections in academia, sliced again into teaching and research sub-networks.

Observations:

The three components of the proposed approach have the potential to influence the formation of connections in an academic network for the following reasons:

1) The short interaction between pairs of courses is designed to increase the probability that a pathway forms between two nodes in the academic network by addressing the practical problems that raise the threshold for interaction.
2) Finding a means to make common progress lowers the threshold for interaction.
3) The free rotation of pairs of courses provides a mechanism for creating multiple, connected hubs in the network.

Despite the emphasis of this approach on dissimilarity, the driving force of progress establishes a common ground and a way for “like” to recognize “like.”

This approach leaves the participants relatively independent and mobile. As a result, this could be a highly gregarious scheme that affects the distribution of long-range connections. To analyze quantitatively an interdisciplinary teaching network, including the contributions of the spectrum of co-existing approaches to such collaborations, one would have to monitor the time evolution of the teaching connections among faculty and study their distribution properties.

Conclusion

A model for interdisciplinary interaction in an academic institution implemented with only small changes to existing courses and striving for increased depth within the discipline through the interdisciplinary interaction has been presented. Three examples of short, joint events between different pairs of classes and the different ways in which they were used to reinforce course material were described. The scheme provides a platform for students in strikingly different disciplines to gain experience communicating with each other and to develop a mutual respect for each other's area of expertise. The scheme also provides a practical way to reduce the degree of separation between remote parts of campus. It would be interesting to make a detailed comparison between the evolving interdisciplinary network on campuses and the behavior of small world networks, or alternately, to ask what one might learn from network analogs in improving such interactions.

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