

Superstrings: A Theory of Everything for Everyone?

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Context for the Course

- ❑ One-semester, general-education course originally designed for non-STEM students
- ❑ Developed under the auspices of Gustavus' Rydell Distinguished Professorship Program
- ❑ Team taught, four days per week for 14 weeks
- ❑ Formulated around Jim's DVD lecture series "Superstring Theory: The DNA of Reality" from The Teaching Company

Goals of the Course...

- Introduce and explain the process of science, and of theoretical physics in particular, to a non-STEM audience
- Use the popular currency of the topic of string theory as an attractive window into the subject
- Utilize the presence of a world-renowned expert on the subject to attract a student audience.

... Goals of the Course

- Have the students make/understand connections between:
 - Mathematics and Science
 - Culture and Science
 - History and Science
 - Philosophy and Science
 - Religion and Science

Course Delivery...

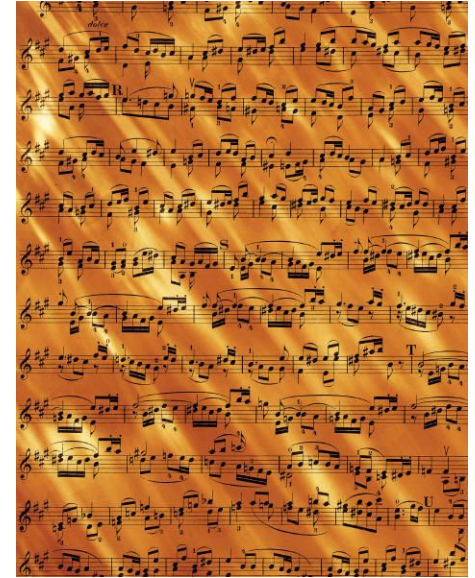
- 24, 30-minute DVD lectures with substantial use of CGI to convey the results of esoteric mathematical calculations. These were each coupled with a group activity, demonstration, discussion or mini-lecture as either introduction or follow-up.
- 24 supplemental 50-minute lectures
- 5 laboratory experiments
- 3 supplemental video presentations

... Course Delivery

- Homework in the form of outside readings, written essays, computer-simulation exercises, mathematical exercises
- Midterm and final papers
- Final course evaluation instrument measured student perception of each aspect of the course and measured their understanding of physics-related content

Instructional Paradigm – A Musical Score

- ❑ Even if you can't read a musical score, you can listen to the result being played by an orchestra, and can learn to appreciate and understand some nuances of how it was composed.
- ❑ Even, if you can't read the mathematics, upon seeing its results "played" by computer graphics you can learn to appreciate and understand some nuances of what it means.



$$F_{\underline{a}\underline{b}} \equiv \begin{bmatrix} 0 & E_x & E_y & E_z \\ -E_x & 0 & -B_z & B_y \\ -E_y & -B_z & 0 & B_x \\ -E_z & -B_y & -B_x & 0 \end{bmatrix}$$

Extension of the Analogy

- It is possible to teach non-musicians how to read a musical score in a conceptual fashion.
 - Treble clef vs. bass clef
 - Fortissimo vs. pianissimo
 - Pizzicato vs. legato
- It is possible to teach non-mathematicians how to read mathematical expressions in a conceptual fashion.
 - Derivatives
 - Differential equations
 - Matrices
 - Operators
 - Invariants

Course Enrollment – Oops!

- ❑ Course was originally intended for non-STEM students, and enrollment capped at 24 due to limited lab equipment
- ❑ Notoriety of Professor Gates within the math and physics departments led to a student cohort that was
 - 9 physics majors (freshman through senior)
 - 4 math/computer science majors
 - 11 others

Physics Content

- Archimedes Principle
- Traveling and Standing Waves
- E&M; electromagnetic waves
- Optics and Polarization
- Thermodynamics and Statistical Mechanics
- Special and General Relativity
- Quantum Physics and Spin
- Stellar Astrophysics
- Elementary Particle Physics
- String Theory
- Supersymmetry

Mathematics Content

- Trigonometry
- Calculus
- Geometry in Higher Dimensions
- Non-Euclidean Geometry
- Coordinate Transformations
- Linear Algebra – matrices
- Group Theory
- Clifford Algebras

Additional Materials

- C.P. Snow, "The Two Cultures"
- E. Wigner, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"
- Timothy Ferris, "The Creation of the Universe"
- Ian Hutchinson, "James Clerk Maxwell and the Christian Proposition"

Student Responses...

- "I was not sure that an English major like myself would be able to understand theoretical physics. To my surprise, however, I found that I was more qualified than I had known, and that I could understand most of the concepts presented in class."
- "Although I have taken many science courses and am currently planning on majoring in biology, I never really understood the nature of science until I took this course. "

... Student Responses...

- “As a physics major, I tend think of science only in terms of the results: theories, laws, and equations, but this string theory class opened my eyes to the broader meaning of science, as knowledge of our reality and the processes by which it is obtained.”

... Student Responses

- “Before I had the opportunity in this class, I thought of science in a way that many non-STEM people think of it—as something for people who like memorizing facts and formulas, and people who like solving problems, but not for people who like thinking critically. After seeing the inner-workings of how science moves from one topic to another, though, I can see how similar the STEM and non-STEM disciplines really are. Hopefully, we will one day be able to realize the dream expressed by Charles Percy Snow in *The Two Cultures*, and people will be able to see the similarities in these different disciplines and learn as much as possible from one another.”

Would You Like To Try This?

- We are eager to find collaborators interested in further developing this course idea.
- You don't need to know much about string theory. (Look at me!)
- We would like to share the resources we have developed.

Available Resources

- DVD Series “Superstring Theory – The DNA of Reality” from The Teaching Company (academic discount \$70) (www.teach12.com)
- Course outline, reading list, lab exercises, simulation exercises, etc.
 - Steve: mellema@gustavus.edu
 - Jim: gatess@wam.umd.edu