Project-based Course Design for Relativity

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Abstract

The small enrollments that are typically found in courses on relativity permit a project-based course design. We will outline a few projects that could be used in a course on relativity or gravitational wave astronomy. Whether the projects are open-ended depends on the level of the course, but each allows for plenty of room to explore. Each project ends in a project fair where students present their work. In addition to promoting an intrinsic motivation to learn the content that is required to complete the project, students work in teams and develop soft skills that are essential for their careers: the ability to work in collaborative teams; technical writing; outlining, designing, and completing a project; and presenting their work.

Team-Based Learning

Team-based learning (TBL)[1] has several features that facilitate project-based course design.

- *Groups:* Students work in teams, perhaps for the entire semester. Most of the in-class time is spent on group work.
- *Accountability:* Students must be accountable for their individual and group work.
  - *Reading:* Students annotate the textbook using Perusall.
  - *Out of class homework:* If relevant, students work out solutions to any problems individually (in black pen) and then working with their teams on corrections (in blue pen).
  - *Group work:* Peer evaluation plays a key role in assessing the work of the individual members of the group. Students receive the comments of their team members. While having a finite amount of points to distribute, students provide scores for other group members and for themselves.
  - *Readiness Assurance Activities (RAA):* Exams are non-traditional. They occur once the related reading is due but well before the project is to be completed. The RAA is an exam (taken online) that students take for individually during the first part of the period and then as a team during the second part of the period. A student's score is the average of the individual and team score.
- *Feedback:* Timely and continual feedback is critical for a project-based course.
  - Students receive immediate feedback on RAAs once the team-based portion is completed. Teams have the opportunity to write appeals. Also, the instructor discusses main misconceptions immediately following the RAA.

Assignment Design and Project Briefs

Assignment Design: To engage students and prevent team members from working in isolation, it is necessary to have them spend much of their time working on the project while in class. All teams work on the same project and share results simultaneously. Each project potentially culminates in a project fair where they present their work to a wider audience. The emphasis is take the opportunity to further develop students' soft skills. Provide a project brief[2] for students at the beginning of each project that outlines the constraints on the project and the expectations of the teams. Students turn in a set of deliverables: team contract, project proposal, project report, and peer assessment.

Build a table-top interferometer

Farr et al. (2012)[3] discusses the value of using a table-top interferometer for demonstrations in a classroom. Providing students with a small budget can allow for them to design and build and interferometer. Teams can compare sensitivities to known audio or seismic sources and explain their choices and the physics involved at the project fair. Connecting the voltage from a photodiode to a speaker can allow for the audience to listen to the response of the interferometer.

Write a movie script

Students are familiar with the movie *Interstellar*. Similar to Kip Thorne's role for that movie[4], students are to employ relativity to produce scientific content for a new movie script. Like many blockbusters, the plot is just details.

Data Analysis of GW150914

The data of the first gravitational wave event GW150914 is freely available at the LIGO Open Science Center[5] as is a tutorial for carrying out signal processing of the event. A project can involve students performing the analysis for themselves.

Flowchart of numerical relativity code

Another project is constructing a flow chart of a numerical relativity code as can be found on the Einstein Toolkit[6]. Once completed, students then further investigate how one or more components work and potentially make minor improvements to an otherwise functioning code.

Design a gravitational wave observatory

Add or remove some constraints to current detectors (e.g., amount of funding, ground-based or space-based) and have students design a gravitational wave observatory. A personal favorite, students investigate the value of having 3 arms versus two in space-based detectors.
For their detector design, students must describe what sources will be detectable and to what range.

Perusall - Get students to read the textbook!

Perusall[7] offers a way of allowing students to annotate the textbook online. Students are able to make comments and ask questions that are viewable by other students and the instructor. It starts an asynchronous conversation where students do not have to wait until class to have their questions answered.

- Comment or ask questions either on text or comment on figures.
- *Grading:* The quality of the comments are graded automatically by Perusall.
- *Confusion Reports:* For each reading assignment, Persuall generates a confusion report. On a single page, it lists the three topics that students found the most confusing and examples of their comments.
- *Buying the textbook:* Students purchase the online textbook directly from Perusall. Perusall contacts the publishers to agree on a price.
- *PDFs:* You can upload and annotate PDFs for free.
- *Journal Clubs for Research Groups:* Perusall does not need to be used for a course, but instead can be used for a research group.
- *LaTeX compatible:* One key feature for our audience is being able to write equations in comments using LaTeX.

Have an idea to share?

Share your ideas or references by writing them on a notecard and pinning them to the board. A compiled list will be available by email.

Orange notecards are for introductory courses at the graduate level.

Red notecards are for courses at the graduate level.

Blue notecards are for *other*.

Contact

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References

1. L. Michaelsen, M. Sweet, D. Paramelee, *Team-Based Learning: Small-Group Learning's Next Big Step*, New Directions in Teaching and Learning, Number 116, Winter 2008.
2. Based on Eric Mazur's design of the introductory physics course AP-50 at Harvard University.
3. B. Farr, G. Schelbert, and L. Trouille. *Gravitational wave science in the high school classroom*, Am. J. Phys. **80**, 898 (2012)
4. Thorne, Kip, *The Science of Interstellar*, W.W. Norton & Company, 2014
5. LIGO Open Science Center (https://losc.ligo.org)
6. The Einstein Toolkit: http://einsteintoolkit.org/
7. Persuall (http://www.perusall.com) Developed by Eric Mazur, Gary King, Brian Lukoff, and Kelly Miller (Harvard University).

Other Resources

1. Matt Choptuik's projects in numerical relativity courses: http://laplace.physics.ubc.ca/People/matt/Teaching/previous.html
2. MIT Open Courseware *Exploring Black Holes: Relativity & Astrophysics:* http://ocw.mit.edu/courses/physics/8-224-exploring-black-holes-general-relativity-astrophysics-spring-2003/projects/
3. Classroom activities developed at Penn State: http://cgwp.gravity.psu.edu/outreach/activities/
4. Ian Morrison (McGill University) Mathematica Projects: http://www.physics.mcgill.ca/~imorrison/Phys514/Projects/projects.html