PROJECT OUTCOMES REPORT

This project investigated how undergraduate students use spatial reasoning to make sense of fluid transformations observed in physical models of oceanic and atmospheric processes — specifically, demonstrations using density tanks and rotating tanks that are common in introductory oceanography and atmospheric science courses. As a BCSER: IID project, it had two equally important goals: advancing fundamental STEM education research and supporting the professional development of the PI as an emerging researcher at the intersection of geoscience education and cognitive science.

Intellectual Merit

Understanding how students think and learn in fluid-Earth science disciplines is a largely uncharted area of research. Fluids — unlike the rocks and rigid structures that dominate much of traditional geoscience — do not behave as solid objects, and the spatial reasoning required to interpret fluid behavior is poorly understood. This project produced new knowledge about student mental models of fluid processes and contributed to theory-building both in cognitive science and geoscience education.

We conducted two rounds of semi-structured interviews with 59 undergraduate students, using density and rotating tank demonstrations as the basis for think-aloud inquiry. Analysis of interview transcripts, participant sketches, and video data revealed that students arrive in courses with coherent but systematically incorrect mental models of how fluids behave. In the density tank work, many students predicted that fluids of different densities would remain in vertical layers or mix quickly — both inaccurate ideas. In the rotating tank work, students drew on mental models of fluids spinning up from rest, leading them to predict that rotation would enhance mixing — the opposite of what actually occurs. These misconceptions are rooted in everyday experiences that students inaccurately apply to geophysical fluid contexts, and demonstrations alone do not reliably correct them: students showed improved reasoning only about half the time after observing a demonstration.

These findings are documented in peer-reviewed publications and manuscripts currently under review, including a theoretical contribution — developed collaboratively with a broader research group — that examines a dominant framework for understanding spatial thinking in geoscience education and proposes an adjunct strategy applicable to fluid-Earth contexts.

Broader Impacts

The broader impacts of this project operated on several levels: infrastructure, student training, professional development, and the seeding of a new research direction.

This project established a fully equipped fluid-Earth science research laboratory at Towson University, housing a rotating tank system now used for both research and undergraduate classroom demonstrations. This facility supports ongoing research and provides students with direct, hands-on experience with the physical models that motivate this line of inquiry.

The project supported the training of a Master's-level graduate research assistant whose thesis drew directly on data collected through this project. She defended successfully at the close of the project period, gaining skills in qualitative research methods, data analysis, and scientific dissemination, and presented her work at a national professional conference.

The professional development component of this BCSER project was designed to expand the PI's capacity to conduct cognitive science research — and it did. The project supported formal coursework in cognitive psychology, sustained mentoring from a leading cognitive scientist, and participation in an active cognitive science research group. This immersion in cognitive science methods, theory, and community advanced the PI's ability to conduct and publish research at the intersection of geoscience education and cognitive science. The mentoring relationship that developed over the course of this project grew into a full research collaboration — producing co-authored publications, a jointly led research interest group, and ultimately a new NSF-funded project in which the PI and mentor serve as co-investigators. That follow-on project, investigating how students and experts reason about atmospheric processes during convective field studies, is a direct intellectual descendant of the work begun here and represents a concrete return on the investment NSF made in this capacity-building grant.

Results from this project were shared broadly through peer-reviewed publication, conference presentations, and invited lectures at research universities. A workshop delivered at a national geoscience education conference brought these findings directly to fluid-Earth science instructors, connecting the research to classroom practice.