**DESIGNING AN EARTH AND SPACE SCIENCE COURSE SEQUENCE FOR IN-SERVICE TEACHERS.**

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**Introduction:** In 2011, faculty in the Department of Science/Mathematics Education at the University of Texas at Dallas redesigned our Masters of Arts in Teaching (MAT) programs in both Science and Mathematics Education. We created course sequences to enhance content knowledge, pedagogical strategies, and teaching resources for four different areas of emphasis: Mathematics, Physical Sciences, Life Sciences, and Earth and Space Sciences (ESS). Two of the courses in the ESS sequence, *Astronomy* and C*omparative Planetology*, are space science based and as such draw heavily from NASA-related content. The overarching goal in course and course sequence design is to provide teachers with the knowledge and resources they need to be successful with their own students.

**Background:** The Department of Science/Mathematics Education (SME) [1] at the University of Texas at Dallas (UT Dallas) has historically provided professional development to in-service teachers (actively in classrooms) of grades K–12. Professional development is provided through multiple venues, including informal workshops and formal graduate coursework. Grant programs, such as Teacher Quality Grants [2], the Texas Regional Collaboratives for Excellence in Science and Mathematics Teaching [3], Education and Public Outreach (EPO) for NASA's Coupled Ion Neutral Dynamics Investigation (CINDI) [4], and a NASA IDEAS Grant [4] had significantly impacted MAT courses in the years before the MAT program redesign effort. The Science Education MAT maintains its historical inclusive approach, and is open to science teachers regardless of grade level taught or undergraduate major. The broad spectrum of backgrounds and teaching needs for Science Education MAT students makes course design and instruction particularly challenging for the faculty members involved. In addition, courses in Physical Sciences and ESS sequences may be taken by graduate students in Physics and Geosciences as well as upper level undergraduate students in the UTeach Dallas science and mathematics teacher certification program [6].

**Meeting Standards By Design:** Three essential principles drove the redesign of coursework for the Science Education MAT: 1) What do teachers need to teach? 2) What fundamental concepts are essential for teachers to know in terms of building their own understanding of the content studied? 3) What skills should science teachers have in order to be successful at teaching the required science content in their own classrooms?

Content standards required for Texas public schools are the *Texas Essential Knowledge and Skills* (TEKS) [7]. The TEKS were, and remain, a driving factor in our course designs. Other changes in the Texas science education also impact our courses, such as the needs of local middle and high schools designated as Texas Science, Technology, Engineering and Mathematics (T-STEM) Academies [8]. T-STEM Academies focus instruction around a Problem-Based Learning (PBL) [9] model, "in which students learn through facilitated problem solving."[10] In addition, our course and program designs are influenced by research and innovations in teaching and learning at the university level and our replication of the UTeach teacher preparation model [11] that began in 2008.

**The Texas Educational Landscape:** New science TEKS were adopted in the 2010-2011 school year. Among the significant changes in ESS were the addition of an optional capstone ESS high school course and a complete revision of the optional high school astronomy course. In middle school, habitability in a planetary science context was added, specifically "analyzing the characteristics of objects in our solar system that allow life to exist"[7]. While the new ESS high school course is exposing more Texas high school students to ESS content than was previously the case, most ESS content continues to be taught in middle school. The majority of teachers assigned to teach ESS content, regardless of grade level, have little to no Earth science or space sciences background.

Teacher certifications in the state of Texas include composite science for grades 4-8 and 8-12. A teacher with a composite science certification is considered highly qualified to teach in any science class, regardless of their own undergraduate degree or formal coursework. The composite certification means that teachers assigned to teach ESS content cannot be expected to have even basic background knowledge in geosciences or astronomy. To meet the needs of ESS content novices who are required to teach ESS content, our MAT coursework must provide mechanisms to allow students to develop an understand of the Earth, its interconnected systems, and our planet's place within the broader cosmos.

The Dallas Fort-Worth Metropolitan area is also home to several school districts implementing a PBL instructional model. For teachers, PBL can be daunting, particularly in terms of assessment and assurance that tested content will be covered.

**Experiential Learning:** While other courses include PBL components, one course in the ESS sequence – *Rockin' Around Texas* – is built exclusively around a PBL model. Each major activity is centered around a driving question. Our first question in this new course was, "What tools, resources, and understanding are needed in order to lead a geology field trip anywhere in Texas?" Students and Montgomery (a paleoecologist) first worked in groups to decide what they did, and did not, know. Groups then developed a plan of action that involved a detailed concept map. Following weeks of work within the arena of the driving question, the students arrived at a wide array of logical, illustrated, and well referenced conclusions and presented their results to their peers. All evaluation is conducted using rubrics, and as in our professional world, peer evaluations are critical. The learner directed nature of this immersive PBL course provides strengths in the depth of understanding and challenges for ensuring that fundamental concepts beyond the immediate scope of the project are covered. As such, it provides an essential model for teachers implementing PBL instructional designs in their own classrooms.

**Through the Lens of Space Science:** Two courses in the main ESS sequence, *Astronomy: Our Place in Space* and *Comparative Planetology,* are taught by Urquhart (a planetary scientist) and are explicitly space science courses. However, for both, understanding the Earth in its context as a planet is critically important. Ideally, astronomy is the first course taken in the ESS sequence.

*Astronomy: Our Place in Space* introduces participants to inquiry investigations reflective of those teachers might assign students in typical precollege classrooms. Students are, for example, assigned to keep a five week log of their own lunar observations prior to modeling of the Sun-Earth-Moon system [12]. An exploration of the reason for seasons [13] is interwined with discussions of energy balance, resulting in creation of an activity on that subject which we will highlight in our presentation. Scale in the solar system and beyond are modeled with embedded assessments [14]. The role of space weather in the Sun-Earth-System is introduced via embedded versions of workshops highlighting CINDI an other NASA heliophysics content, with separate pre/post assessments [15]. *Stars and Planets*, the middle school astronomy curriculum field tested with Urquhart's IDEAS grant, is a springboard for moving beyond the solar system into topics of stars and galaxies, and cosmology [16]. PBL experiences are present, but in the form of small projects. Pre/post assessments on general astronomy, phases of the Moon, and seasons [17, 18, 19] measure learning gains.

*Comparative Planetology* had, like *Astronomy*, been taught prior to the 2011 revisions. While *Astronomy* was refined, *Comparative* was retooled to provide the foundation for ESS content teachers were required to teach. A new emphasis on plate tectonics in the TEKS, for example, required more time be spent on aspects of geophysics that are unique to Earth. In *Comparative*, findings of active and past planetary missions are continually brought back to comparison to the Earth. General geoscience prinicples that affect Earth as a planet, and what we can learn from the rock record preserved on other planetary bodies, are highlighted. Using K-12 classroom-accessable planetary data and defending competing hypotheses within the current planetary science community provide mechanisms to ascimilate and assess content learned. By design, the first implementation of new and retooled courses in the ESS sequence shared a single graduate assistant with a strong geoscience background. The graduate assistant helped identify what topics require greater emphasis in each course.

ESS and NASA content is also embedded, where appropriate, in *Conceptual Physics I-III* as part of the Physical Science course sequence taught by Urquhart. The final course of the ESS sequence is *Evolution*, taught by Montgomery. We made the decision to leave *Astrobiology* as an elective which can serve as a capstone course bringing together teachers with an emphasis in each of the three science content areas for our Science MAT. Planetary properties related to habitibility are therefore topics covered in *Comparative*.

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