INSTRUCTOR NOTES

Materials Required (all provided by the instructor):

- Pre-readings on the different evidences for plate tectonics
    - Evidence readings (split between the class so ¼ of the students are 'experts/theorists' in one topic before coming to class): (1) Earthquakes, (2) Volcanoes, (3) Faulting, (4) Surface and Seafloor Topography and ages
- Global maps - to identify plate margins (the direct links are provided as background/source information; cleaned up jpg and pdf versions to print for lab use are attached here: https://drive.google.com/drive/u/1/folders/1oLwKcc_FQ4FGlsS1J8g5c00THuvhje2I)
    - Earthquake locations:
        - https://commons.wikimedia.org/wiki/File:Map_of_earthquakes_1900-.svg
        - http://plateboundary.rice.edu/quakes.11.17.pdf
    - Volcano locations
        - https://i1.wp.com/www.cccarto.com/icons/world_volcano_map.jpg
        - http://plateboundary.rice.edu/volcano.11.17.pdf
            - Other interesting websites with information on volcanoes (these sites may change, titles are included for search purposes in the event that the links are broken):
                - Volcano World | Your World is Erupting (http://volcano.oregonstate.edu/)
                - Global Volcanism Program: Worldwide Holocene Volcano and Eruption Information (https://volcano.si.edu/)
                - Monitoring Volcanoes (US National Park Service) (https://www.nps.gov/articles/volcano-monitoring.htm)
                - This Map Shows Earth's Volcanic Activity Over The Past 10,000 Years (Forbes) (https://www.forbes.com/sites/davidbressan/2019/11/02/map-shows-earths-volcanic-activity-over-the-past-10000-years/#1332d51217ca)
    - Continental surface & Sea floor topography:
        - https://topex.ucsd.edu/marine_topo/mar_topo.html
        - http://www.physicalgeography.net/fundamentals/10p.html
        - http://plateboundary.rice.edu/age.24.36.pdf
        - https://www.ngdc.noaa.gov/mgg/ocean_age/data/2008/ngdc-generated_images/whole_world/2008_age_of_oceans_noplates.pdf
    - Fault maps
        - https://eoimages.gsfc.nasa.gov/images/imagerecords/88000/88415/dtam.pdf (I made an edited version of this with just the faults)
    - Plate Boundaries? - for end of lab or post activity to affirm/check their theories
        - http://plateboundary.rice.edu/downloads.html

        - https://www.nps.gov/subjects/geology/plate-tectonics-evidence-of-plate-motions.htm
- Regional maps - to identifyID plate margins (the direct links are provided as background/source information; cleaned up jpg and pdf versions to printing for lab use are attached here: https://drive.google.com/drive/u/1/folders/1oLwKcc_FQ4FGlsS1J8g5c00THuvhje2I)
    - Earthquake epicenters with depth & magnitude
        - https://seismo.berkeley.edu/seismo.real.time.map.html
        - https://earthquake.usgs.gov/
        - http://npdp.stanford.edu/eq_historical_catalog
    - Volcanoes with type/composition
        - Try using the GVP world volcanoes KMz and csv files for google earth and zooming to the region of interest (file in group 15 folder - courtesy of group 17)
        - https://volcanoes.usgs.gov/index.html
    - Continental surface & Sea floor topography - elevations
        - https://topex.ucsd.edu/marine_topo/mar_topo.html (this one is interactive and awesome for regional maps)
        - https://opentextbc.ca/geology/chapter/18-1-the-topography-of-the-sea-floor/
        - https://www.sciencephoto.com/media/159936/view/pacific-ocean-topographical-map
    - Ocean floor age / magnetic anomalies
        - https://sos.noaa.gov/datasets/age-of-the-seafloor-topography/
        - https://www.ngdc.noaa.gov/mgg/image/crustalimages.html
    - Fault maps & Local photos: aerial/oblique/ground
        - Surface features & rock types with clear offset
        - https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf
    - GPS data - for the end of lab or post activity to affirm/check their theories
        - https://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html
    - *Optional* Bio material / fossil maps - could be used for homework or lab exam question (post lab activity)
    - Instructional videos
    - GeoScience Videos YouTube Channel (aka McConnell Videos) - https://www.youtube.com/c/GeoScienceVideosDavid McConnell:
        - **Divergent Plate Boundaries: https://youtu.be/g4DdNw-Zd2Y**
        - **Convergent Plate Boundaries: https://youtu.be/75di2vdSg5U**
    - **Transform Plate Boundaries: https://youtu.be/tuKNtQ7Hupg** The Educational Multimedia Visualization Center of the Department of Earth Science, University of California - Santa Barbara (aka Attwater Animations) -

http://emvc.geol.ucsb.edu/1_DownloadPage/Download_Page.html#GlobalTectonics

The suggested sequence for the lab is as shown below (as written here this should take ~2.5 hours):

- **Pre-lab:** Each student is given a Student Handout and one of four pre-lab reading passages on evidence related to one of the following features: earthquakes, volcanoes, topography & seafloor ages/anomalies, faults. (**Estimated time 30-45 min. - outside of class)**
    - **Same reading for each 'expert group'**
    - Students are asked to write down their thoughts or ideas about their reading. Prompts given to guide student thinking (see pre-lab reading handouts)
- **Beginning of the lab**, students come together in their **'expert' groups** and discuss their pre-lab reading. **(~10 min).** (a link to information on Jigsaw activities is provided below)
    - Students in each group should come up with group shared ideas. Students write down their shared ideas on their 'student handout' to be shared with their mixed group and to be turned in at the conclusion of the activity.
- **Expert Groups examine global maps** students will record their observations individually on their 'student handouts' **(~15 min)**
    - Prompt: what patterns do you see in the provided global maps?
    - Activity: create a bullet-point-list of the patterns and observations seen (e.g. patterns between the locations, depths, and magnitudes of different earthquakes)
- **Mixed Groups (~15 min).** Groups assign a reporter, students will record their observations individually on their 'student handouts' and the reporter will share the groups ideas with the class in the following discussion
    - Students reform into groups with one member from each expert group; experts report their findings on the global maps to a group and share insights with each other
    - Prompts: do the patterns overlap? How do you explain what you see?
    - Students add to their notes of these ideas.
- **Full-class discussion (optional if short on time)** of plate boundaries: reporter from each group share the patterns of their data and the comparison notes instructor can comment on points that need further clarifications **(~15 min)**
- **Mixed groups** are given regional data sets to study (at least three unique sets: transform (e.g. San Andreas), divergent (e.g. Atlantic mid-ocean ridge), convergent (e.g. Andes subduction zone)) - these data sets include the more detailed maps with multiple features (i.e. depths of quakes/magnitudes, volcano compositions/types, fault maps/aerial photos showing offsets etc.) assign a reporter **(~20 min).**
    - Students make more observations and find more patterns (e.g. deep quakes, and certain volcanoes, majority reverse faults, etc..)

    - Goal is to come up with a list of characteristics of surface features that exist in different plate boundary types
    - Questions: What do you think is happening at this plate boundary? What is the evidence? What type of boundary do you think this is? What other information would you like to better confirm this hypothesis?
    - Conclusion: provide students with GPS data - does this support your hypothesis or do you need to revise your hypothesis?
- **Full-class discussion:** the idea here is to bring together the identifying characteristics for each boundary **(~15 min)**
    - Each group reports their observations and hypothesis
    - Class creates a class list of observations and hypotheses on the whiteboard
    - Class can also create a list of ambiguous characteristics - i.e. exists in two/all boundary types, or not consistent for different boundaries, etc.
- **Lab assessment activity:** (New Groups) students are given a new regional map/set of data **(~10 min)**
    - 4-5 new data map sets labeled (e.g. Anatolia Fault zone, East Aftrican Rift, Himalayas, Japan Subduction, Caribbean subduction & Transform, Hawaii hot spit-trick)
    - Group has 2 min per-map set to make quick observations and come up with a hypothesis for the type of plate boundary - rotate maps between the groups -- multiple 2-min rounds (this can be adjusted with more time per set and fewer sets)
- **Entire class**
    - Quick "popcorn" discussion of the hypotheses for each set **(~5 min)**
    - Watch (or share for later viewing) some Attwater animations or McConnell videos to show plate motions - **(~10 min)** - *links for videos above in Teaching Material section;*
- **Final activity with original 'expert' group** - assign a group recorder to write down these thoughts and questions for the group (to be turned in at the end of class) **(~15 min)**
    - Students now return to the evidence they read about in their pre-lab and use the information/knowledge they have gained to come up with more thoughts, revised theories, more questions, etc.
- **End the lab with a minute paper** surveying students' with prompts such as clearest/muddiest point, favorite thing, new things learned, and/or new thoughts and questions. **(~3 min)**

- Optional exercises (could be homework or lab exam questions too)
    - Describe surface features from your hometown (i.e. mountains, faults types, etc.) and hypothesize what type of plate boundary exists/existed to create such features. And why?

- Given all of the global maps (quakes, volcanoes, faults, topo, gps) students draw over a blank world map with where they think the plate boundaries are and what type, then provide a map of the correct plate boundaries and have them note where they were wrong and either ***explain why or write down any questions*** if they are confused about the actual boundary type
- Given a tectonic map labeled with the plate boundary type - mark a few regions and have students identify and explain a few key features they know to exist there (either prior knowledge or a bit of research on the spot) - use those features to ***explain*** the obviousness of the boundary type or to show the confusing part about that particular boundary.
- Provide post-lab readings with more details describing how the features we looked at support the Plate Tectonic Theory and have students reflect again
- Provide reading in support of the new theory called Convection Tectonics and have students compare the two theories and use the earning we did to support one over the other or show how the PT theory was preliminary and now with our new observations how scientists can make and support this new CT theory
- Provide biomarkers/fossil data/maps and have students explain how this further supports or confounds the plate tectonic theory.
- Provide Yellowstone National Park and Hawaii Islands volcano data (age, location) and have students answer the following questions:
  - What is happening here? Is it a plate boundary?

Teaching tips/barriers to learning:

- Many of the maps used in this exercise use colors to convey information; this may pose a barrier to students with color vision deficiency (CVD). The International Association for Geoscience Diversity (IAGD) has resources including links to free software that can transform color displays into forms more useful to students with various forms of CVD. Students should be offered digital versions of the maps provided and links to transformative software.
  - IAGD CVD Information and Resources: https://theiagd.org/forums/topic/color-vision-deficiency-cvd/
- Pedagogy in Action
  - Jigsaws: https://serc.carleton.edu/sp/library/jigsaws/index.html
  - Cooperative Learning: https://serc.carleton.edu/sp/library/cooperative/index.html
  - Guided Discovery: https://serc.carleton.edu/sp/library/guided_discovery/index.html
  - Teaching with Data: https://serc.carleton.edu/sp/library/teachingwdata/index.html
- Assigning students to expert groups with assigned readings in a prior class section is preferred.
  - It is important to stress to students that preparation is critical to this exercise; participation points may be given to students who show evidence that they have prepared.

    - Some "experts" may be absent; this can be addressed by determining the mixed group assignments at the beginning of the class session (some groups may have more than one "expert" on a topic).
    - Some "experts" may not have prepared (read the assigned reading &/or taken notes to share). This can also be addressed by emailing students a reminder one day prior to the lab and via their discussion within the "expert" group at the beginning of the lab.
    - Some students may not have attended the class session when "experts" were assigned; they can be assigned to an expert group at the start of class and the other members of that group can bring them up to speed.
- For the video portion: Instructor *can show all videos to the class or a few Attwater animations then each group that worked on a specific type of boundary watches their specific video (McConnell videos on divergent, convergent, transform) and all videos can be linked on the course page of the rest of the students to view later*