I. Introduction
Lecture-Tutorials (L Ts) are a research-validated technique to incorporate active-learning into content-heavy, traditionally lecture-based courses. LT activities consist of worksheets, completed in-class in pairs or small groups, which are designed to help students learn conceptually difficult material. Founded on the constructivist learning principle that new knowledge is built on prior knowledge, these activities seek to systematically elicit students' existing ideas about a topic, confront any potentially problematic misconceptions that may exist, and offer a resolution to facilitate new conceptual development. Research done in the field of undergraduate astronomy education has found that the use of LT activities improves student learning of conceptually difficult topics beyond what is typically achievable by lecture alone [1,2].

II. Context
- Astronomy 150 is one-semester introductory special-topics course for non-majors.
- The Fall 2015 topic was cosmology (the origin and evolution of the Universe).
- 34 students were enrolled, with a mix of astronomy background and year in school.
- The course followed a traditional format utilizing a textbook and lectures for the majority of content delivery.

III. Methods
- In order to improve the quality of instruction, a new suite of five cosmology-specific LT activities were implemented throughout the semester.
- All LT materials, including assessment tools and rubrics, were developed by Wallace, 2011 [3] and were selected to permit comparison to previously published results.
- LT activities were used to reinforce instruction of four core cosmology topics that have been identified to be conceptually difficult to learn [4].
- Student learning gains for each topic were measured using four corresponding concept inventories administered at the beginning and end of the semester.
- An effort was made to adhere to the best practices for LT implementation, as outlined by Brogt, 2007 [5].

<table>
<thead>
<tr>
<th>Inventory ID</th>
<th>Topic</th>
<th>LT Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hubble Plots</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>The Big Bang Theory</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>Evolution of the Universe</td>
<td>3*</td>
</tr>
<tr>
<td>D</td>
<td>Dark Matter</td>
<td>1</td>
</tr>
</tbody>
</table>

*Two LTs, one week apart

IV. Results
Despite uniform implementation practices for all LT activities, statistically significant differences in student performance exist between different inventories.

V. Conclusions
- Measured learning gains are consistent with those reported in the literature [2].
- On all four inventories, students performed at least as well as non-LT classrooms.
- Students achieved medium-level learning gains on two inventories, which is rarely achieved through lecture alone.
- Despite uniform implementation practices for all LT activities, statistically significant differences in student performance exist between different inventories.

VI. Acknowledgements
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References