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How to Use the STEM-OP Levels to Support the Engineering Designed-Based Lesson Plan Template in The Framework for P-12 Engineering Learning (Resource Exchange)

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Dr. Emily Dare is an Associate Professor of Science Education at Florida International University. Dr. Dare's research interests focus on K-12 STEM education. In particular, she is interested in supporting science teachers' pedagogy while also exploring their beliefs about teaching and learning. As science classrooms shift towards integrated STEM approaches that include engineering design as a central component, this is especially critical. Additionally, Dr. Dare has a passion for working with K-12 students to understand how changes in classroom instruction towards these integrated STEM approaches impact their attitudes towards and beliefs about STEM fields. In particular, she examines methods that positively impact girls, which may increase the number of women pursuing careers in STEM-related fields where they are currently underrepresented.

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This instructional resource is designed to help K-12 engineering educators create activities for the Engineering Designed-Based Lesson Plan template found in the Framework for P-12 Engineering Learning [1]. The resource is meant to help take topics found in resources such as textbooks, curricula, and standards and create activities that align with the lesson plan template. This tool is not meant to be used in a linear fashion, but each section relates to the other sections, which may require numerous cycles of revision.The newly developed observation protocol is designed to measure the level of STEM integration in K-12 engineering and science classrooms[2].The protocol and Framework for P-12 Engineering Learning use a design-based vision of integration based on two frameworks [3], [4]that centralize the learning of engineering activities in developmentally appropriate content and practices of science, engineering, and mathematics. The effectiveness measures of implementation have not been collected previously. As the template and the protocol are based on the integrative connections of engineering to other disciplines, using them together is appropriate. The series of prompts in the tables below provide suggestions to enhance the Lesson Plan template shared in the Framework using the descriptive levels on the protocol. This resource uses the top levels of the protocol to assist educators with creating high-quality integrated engineering lesson plans.

<table>
<tr><td colspan="2">Engineering Designed-Based Lesson Plan: Engineering Concepts</td></tr>
<tr><td>STEM-OP Item 5: Integrating STEM Content

Description: The content from multiple disciplines includes specific connections between the content areas in the lesson</td><td>STEM-OP Item 2: Contextualizing Student Learning

Description: Explicitly connects the real-world problem or design challenge to the learning</td></tr>
<tr><td colspan="2">Suggested Lesson Planning Prompts</td></tr>
<tr><td colspan="2">How does the inclusion of selected content area(s) assist students with understanding the connections between the disciplines?
What real-world problem or design challenge explicitly connects to what students are learning?</td></tr>
<tr><td colspan="2">Example: Architectural Engineers use the exposed surface area (mathematics) of a building compared to its volume (mathematics) to help design energy-efficient buildings (context through a design challenge). A building's shape is important because heat is lost through the building's outer faces. Heat is transferred by conduction (science) through solids like walls, floors, and the roof. The larger the area of outer faces the more thermal energy (science) is lost.</td></tr>
<tr><td colspan="2">Engineering Designed-Based Lesson Plan: Culturally Situated Context</td></tr>
<tr><td colspan="2">STEM-OP Item 1: Relating Content to Students’ Lives

Description: Students everyday experiences are explicitly connected to the lesson</td></tr>
<tr><td colspan="2">Suggested Lesson Planning Prompts</td></tr>
<tr><td colspan="2">How will the student experiences be explicitly connected to the lesson?</td></tr>
<tr><td colspan="2">Example: Students research the average measurements of length, width, and height of buildings that resemble their homes. Students use the measurements to calculate the approximate surface area to volume ratio of their home to determine the heat transfer efficiency of its design. Then students build a scale model of their house.</td></tr>
<tr><td colspan="2">Engineering Designed-Based Lesson Plan: Career Connections</td></tr>
</table>

STEM-OP Item 10: STEM Career Awareness *Description*: Provide **specific details** about the STEM careers
Suggested Lesson Planning Prompts
Which specific details about STEM careers can be tied to the lesson?
Example: Architectural Engineers use the surface-area-to-volume ratio to design energy-efficient buildings. They enhance the quality of people's life by making sure buildings are designed in an energy efficient, useful manner.
Engineering Designed-Based Lesson Plan: **Relevant STEM Standards Connections**
STEM-OP Item 5*:* Integrating STEM Content *Description*: The content from multiple disciplines includes **specific connections** between the content areas in the lesson
Suggested Lesson Planning Prompts
What unifying concept can connect the disciplines?
Example: For students to understand why architectural engineers use the surface-area-to-volume ratio to help design energy-efficient buildings is an intentional combination of disciplinary standards. The selection of standards is based on the specific connections between disciplines. Combining the Engineering Concepts [1] (EP-QA-5 and EK-EM-2) scaled physical models and geometry properties with the Common Core Mathematics standard[5] (Geometry.A.2) surface area and volume helps to make the connections between surface area and volume. The inclusion of the Middle School Next Generation Science standard [6](Physical Science 3.B) supports why a larger surface area to volume ratio would cause thermal energy loss quickly, reinforcing the understanding of the Common Core Mathematics standard [5] (6 G.A.4) ratio reasoning.

References

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[2] Dare, E. A., & Hiwatig, B. M. R., & Keratithamkul, K., & Ellis, J. A., & Roehrig, G., & Ring-Whalen, E. A., & Rouleau, M., & Faruqi, F., & Rice, C., & Titu, P., & Li, F., & Wieselmann, J. R., & Crotty, E. A. (2021, July), Improving Integrated STEM Education: The Design and Development of a K-12 STEM Observation Protocol (STEM-OP) (RTP) 2021 ASEE Virtual Annual Conference. https://peer.asee.org/37307

[3] T. J. Moore, M. S. Stohlmann, H.H. Wang, K. M. Tank, A. W. Glancy, and G. H. Roehrig, "Implementation and integration of engineering in K-12 STEM education," in *Engineering in Pre-College Settings*, S. Purzer, J. Strobel, and M. E. Cardella, Eds. Purdue University Press, 2014, pp. 35–60.

[4] T. J. Moore, A. W. Glancy, K. M. Tank, J. A. Kersten, K. A. Smith, and M. S. Stohlmann, "A Framework for Quality K-12 Engineering Education: Research and Development," *J. Pre-Coll. Eng. Educ. Res. J-PEER*, vol. 4, no. 1, May 2014, doi: 10.7771/2157-9288.1069.

[5] Council of Chief State School Officers, "Common Core State Standards," 2010. http://www.corestandards.org/Math/ (accessed Nov. 29, 2021).

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