Draft Learning Progression (LP) for Urban Heat Island (UHI) Effect
MADE CLEAR UM Learning Sciences Research Group
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November 28, 2012

	Level 1 (Lower Anchor) "Informal Accounts"	**Level 2** "Causal Sequences with Hidden Mechanisms"	**Level 3** "School Science Narratives"	**Level 4** (Upper Anchor) "Qualitative Model-Based Accounts"
Potential UHI LP indicator based on Jin & Anderson (2012, pp. 1161-1162) "EA" stands for energy association	EA1: Energy is associated with life, conditions, or feelings: Students state that the sunlight enables urban surfaces and air to become hot (by its presence) or cold (by its absence). Students fail to understand that the air continues to warm after the sun goes down.	EA2: Energy is associated with a physical necessity powering hidden processes or under-going changes in hidden processes: Students state that sunlight energy is needed to heat materials in an urban environment, and that different materials absorb different amounts of this energy. Students begin to understand that energy is released from hot objects through invisible radiation.	EA3: Energy is associated with different sources: Students state that energy can come from sunlight or from hot urban surfaces that release infrared radiation. They understand that radiation from the sun can warm surfaces (differentially), and radiation from surfaces can warm the air.	EA4: Energy is associated with its transfer and transformation through different materials: Students state that sunlight is absorbed by urban surfaces (differentially), transforming into sensible or latent heat, kinetic energy, and infrared radiation. This energy can then be transferred to other surfaces, the atmosphere, or space.
Potential UHI LP indicator based on Jin & Anderson (2012, pp. 1161-1162)	ET1: Energy is traced using a cause-effect chain, with actions, functions, physical	ET2: Energy is traced through mixing processes between materials and energy:	ET3: Energy is traced through conversions in physical processes: Students state that light	ET4: Energy is traced through transformations and transfers among different materials:

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"ET" stands for energy tracing	interaction, or conditions acting as causal mechanisms: Students state that sunlight provides surfaces with the conditions for getting hot. They hit/touch surfaces, move inside of them, and are used up or move into the environment.	Students describe processes in which sunlight is mixed with surface materials to make heat. The heat can then move and combine with the air, which becomes warmer.	energy may turn into heat or radiation, which is released into the environment. However, students fail to use the law of conservation of energy consistently as a constraining principle.	Students explain how radiation is absorbed or reflected from the sun, depending on the properties of surface materials. After materials absorb radiation, energy can be transferred to the air through convection or evapotranspiration, or to air or other surfaces through radiation. Students use the law of conservation of energy consistently to explain the urban surface-air energy budget.
Potential UHI LP indicator about the role of different materials "M" stands for materials	M1: Materials are treated as actors that become warm when enablers like sunlight are present.	M2: Materials are used to explain that some surfaces become warmer than other surfaces in response to sunlight, causing a warmer environment.	M3: Materials are used to explain that different surfaces absorb, retain, and transfer different amounts of energy, which then heats the environment differentially.	M4: Materials are used to explain how and why different surfaces absorb, retain, and transfer different amounts of energy throughout the day.
Potential UHI LP indicator about the role of vegetation and water in the urban heat island	VW1: Vegetation and water are identified as factors that enable environments to be	VW2: Vegetation and water are used to describe landscapes that do not absorb as much	VW3: Vegetation and water are used to explain how vegetation provides shade,	VW4: Vegetation and water are used to explain how vegetation provides shade, lowering surface

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effect "VW" stands for vegetation and water	cooler.	sunlight energy or change temperature as readily.	lowering surface temperatures, and water absorbs energy without changing temperature readily.	temperatures, as well as how water in vegetation acts to dissipate ambient heat through evapotranspiration. Additionally, bodies of water can act as "heat sinks," due to water's high specific heat.
Potential UHI LP indicator about mitigation strategies for the urban heat island effect "MS" stands for mitigation strategies	MS1: Students are aware that there are factors that contribute to the heat island effect, but they are not able to identify specifics.	MS2: Students are able to identify the sources that contribute to the UHI (e.g. pavement, lack of vegetation), but are not able to explain how they influence the urban heat island effect.	MS3: Students are able to identify sources that contribute to the UHI effect (e.g. pavement, lack of vegetation), and explain how these sources contribute to the UHI effect, but are not able to use models to predict outcomes of changes to the sources.	MS4: Students are able to use models to predict outcomes when given various scenarios about changing attributes of a UHI (e.g. a park densely populated with trees is converted into an athletic stadium with large parking lots).

Reference:
Jin, H. & Anderson, C. W. (2012). A learning progression for energy in socio-ecological systems. *Journal of Research in Science Teaching*, *49*(9), 1149-1180.
Next Generation Science Education Standards Draft

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