Arizona MESA's Engineering Design Process

An Overview of Aligned Standards Supporting Independent Inquiry (NGSS/CCSS/Etc.)

The following learning standards/goals/skills/habits of mind are organized around Arizona MESA's iterative Engineering Design Process (Explore, Design, Test) and our goals to support youth presentation/publication as well as college planning. When specified, these standards/goals are gathered from the Next Generation Science Standards at nextgenscience.org (NGSS), the Common Core ELA STEM Standards 6-12 (RST), A Framework for K-12 Science Education: Practices, Cross-cutting Concepts and Core Ideas (FFK12SE) and other sources.

EXPLORE

☐ **Read & paraphrase design problem** (success criteria/constraints) with "sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions." (RST.11-12.2 and MS-ETS1-1). Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (ETS1.A)

☐ **Explore Vocabulary**. Determine relevant STEM vocabulary & symbols. (RST.11-12.4)

☐ **Generate Ideas**. Brainstorm a wide variety of ideas (NGSS Appendix F).

☐ **Optimize Design Solutions.** Consider all design variables and select most important variables to optimize in this design cycle. "Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed." (ETS1.C,HS-ETS1-2)

☐ **Process Planning**. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2).

☐ **STEM Research.** Read & summarize other complex STEM texts. (RST.11-12.2&10). Compare & contrast findings; synthesize results. (RST.11-12.9).

☐ **Building from Prior STEM Knowledge or Perform STEM Community Needs Assessments.** Link to past class learning or students' funds of knowledge. Consider how to link home and community with classroom science. "Several approaches build connections between home/community and school science: (1) increasing parent involvement in their children's science classroom and encouraging parents' roles as partners in science learning, (2) engaging students in defining problems and designing solutions of community projects in their neighborhoods (typically engineering), and (3) focusing on science learning in informal environment." (NGSS Appendix D and J).

☐ **Iterative Design/Reflection**. Reflect on recent testing data and research to consider possible new design modifications.

☐ **Broaden Research (Formal or Informal) toward Multiple Sources; Avoid Plagiarism.** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (CCSS.ELA-Literacy.W.11-12.8)

☐ **Address Global STEM Challenges.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DESIGN

☐ **Sketch design ideas** "to illustrate how the shape of an object helps it function as needed to solve a given problem." (K-2-ETS1-2.)

☐ **Develop possible solutions**. "When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts." (ETS1.B, HS-ETS1-3). **"**The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions." (MS-ETS1-1).

☐ **Draw/model prototypes.** Draw scaled orthographic or isometric models. (Appendix NGSS-F1&2.) Such work also helps build spatial reasoning skills (Uttal, 2013) that are predictors of STEM futures (Wai et al., 2009).

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☐ **Evaluate competing design solutions** based on jointly developed and agreed-upon design criteria (MS-ETS1-2). Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem (MS-ETS1-2).

☐ **Evaluate solutions based on available resources.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity (HS-ESS3-1).

☐ **Develop computer simulations.** Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4.)

☐ **Geospatial Mapping.** Analyze or create customized, geospatial maps which provide a helpful visual representation of key design data (e.g. community resources, needs, health, hazards, habitat, climate, etc.). Students use "maps, and other abstract models as tools that enable them to elaborate on their own ideas or findings and present them to others" (3 Dimension 1. SciEng Practices. FFK12SE, Cross-Cutting Concepts). "As students progress, their models should move beyond simple renderings or maps and begin to incorporate and make explicit the invisible features of a system, such as interactions, energy flows, or matter transfers" and eventually incorporate "a range of mathematical relationships among variables (at a level appropriate for grade-level mathematics) and some analysis of the patterns of those relationships … Developing systems thinking and system models supports critical steps in developing, sharing, testing, and refining design ideas." (4 Dimension 2. Crosscutting Concepts. System Models: Progression. FFK12SE). Mapping also helps build spatial reasoning skills (Uttal, 2013) that are predictors of STEM futures (Wai et al., 2009).

☐ **Make Design Choices Based on Society & Culture.** Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2). Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2).

TEST

☐ **Create Testing Procedure/Plan.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved (MS-ETS1-4). Follow complex tech procedures/experiments involving data gathering & analysis. RST.11-12.3.

☐ **Test Design Through Multiple Ways/Contexts.** Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5). Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS3-5)

☐ **Data Analysis: Let "Failure" be a teacher.** Use models, graphs and tables as well as written text to evaluate a STEM problem. RST 11-12.3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-3. During testing, "pay attention to points of failure" and modify design specifically to address "failure points." NGSS Appendix I: Engineering Design.

☐ **Cost Benefit Analyses.** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. (HS-ESS3-2). New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3). Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. HS-ESS3-4 and NGSS Appendix J.

☐ **Evaluate hypotheses** in the context of data. Verify results. (RST.11-12.8.) Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1).

PRESENT/PUBLISH RESULTS

☐ **Make Evidence-Based Argument Citing Research.** Citing specific textual evidence from research & addressing author's gaps/inconsistencies. Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. (RST.11-12.1.) Integrate information and data using diverse formats/tools to address a question. (RST.11-12.7.)

☐ **Analyze Design Pros/Cons and short/long term social/environmental impacts of a STEM design.** "All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment." (MS-ETS1-1) "When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts." (ETS1.B)

☐ **Evaluate a solution to a complex real-world problem** based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. (HS-ETS1-3) Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2)

☐ **Revise for Specific Audience or Purpose.** Make paper or presentation more compelling for particular audience while improving writing quality (e.g. specificity, brevity, clarity). (CCSS.ELA-Literacy.W.11-12.5.)

COLLEGE & CAREER PLANNING

(NGSS. Appendix C: College & Career Readiness.)

☐ Explore and understand pathways for various STEM degrees and careers.
☐ Analyze new STEM technologies, controversies and breakthroughs scientifically.
☐ Begin planning for college and career as it relates to preferred STEM fields.

PARENT/FAMILY/COMMUNITY ENGAGEMENT

(Arizona Quality Standards for Out-of-School Time Programs.)

☐ Engage Family, School and Community through 'meaningful and frequent feedback' on student learning.

NOTE REGARDING GRANT OPPORTUNITY: *The* ***Arizona Center for Afterschool Excellence*** *and* ***Cox Communications*** *have partnered to award the 2014 STEM Mini-Grants. The grants, ranging from $500 to $1,500, will be awarded to Arizona out-of-school time programs that use creative and innovative methods to incorporate or expand the use of STEM-based learning.* ***Special consideration*** *will be given to programs that sign the Make It Count Pledge, demonstrating their commitment to using the Arizona Quality Standards for Out-of-School Time Programs to strengthen the quality of their program.*