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STEM CURRICULUM REVIEW FRAMEWORK

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STEM CURRICULUM REVIEW FRAMEWORK WHITE PAPER

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NASA STEM Educator Professional Development Collaborative

About NASA STEM Educator Professional Development Collaborative

NASA STEM Educator Professional Development Collaborative (EPDC) is a national, diversity-focused professional development system that leverages NASA assets and resources to achieve excellence in STEM Education. As a cooperative effort between NASA and Texas State University, EPDC provides a multitude of face-to-face and online professional development opportunities, and NASA resources for educators in K-12, university, and community settings.

The EPDC scope of work aligns closely with the 2014 NASA strategic goals and objectives; Federal STEM Education 5-Year Strategic Plan developed by the National Science and Technology Council Committee on STEM Education; and national curriculum standards set forth in the Framework for K-12 Science Education, Next Generation Science Standards, and National Common Core Standards in Mathematics. Specifically, EPDC is guided by NASA Strategic Objective 2.4: Advance NASA and the nations' STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets. In addition, EPDC directly addresses the co-STEM priority goals of improving STEM instruction, building and using evidence-based approaches, better serving groups historically under-represented in the STEM field, and building new models for leveraging assets and expertise.

The EPDC model is based on the following five foundational principles:

1) Attention to the educator across the professional continuum
2) Respect for the culture and language of the learner
3) Openness to sharing learning and harnessing the power of scholar/expert partnerships
4) Boldness to leverage the potential of massive online learning and badging systems

5) Commitment to create an innovative national impact evaluation model that gets to the heart of professional learning and behavior change

Strategies for Diverse Student Populations And Respect for Teacher Needs

NASA STEM EPDC is committed to helping teachers provide high-quality STEM education for all students through the use of culturally relevant instructional strategies that promote success among diverse student populations.

Such a commitment requires reaching out to educators and tailoring professional development that meets the needs of their students and addresses their district priorities.

The Minority Serving Institutions Teacher Education Network

The Minority Serving Institutions Teacher Education Network (MSI TEN) is comprised of STEM Education faculty members from Texas State University and five partner MSI universities that provide specialized expertise in the field of culturally relevant STEM pedagogy. The MSI TEN original partner institutions that have EPDC subcontracts to work collaboratively with the Texas State University STEM Education faculty and the EPDC leadership team include the following:

- Norfolk State University
- North Carolina Central University
- University of South Florida
- Salish-Kootenai College
- California State University, Northridge

The MSI TEN faculty have worked collaboratively to: 1) develop a K–12 STEM curriculum review framework; 2) design tools for educators based on the conceptual framework developed; and 3) develop a theoretical basis for operationalizing Culturally Responsive Teaching (CRT) in the STEM classroom. The MSI faculty members are currently piloting this framework in evaluating selected NASA curriculum activities and lessons to identify areas that can be strengthened to make the activities more relevant to diverse student populations. The group is also utilizing the framework to formulate instructional videos and activities to be shared with the EPDC specialists for use with the educators they serve.

MSI TEN faculty members are also engaged in revising both undergraduate and graduate courses for pre-service and in-service teachers to include additional NASA resources emphasizing culturally responsive pedagogy. In addition, faculty are conducting professional development activities for their university colleagues and teacher candidates on these topics.

This paper introduces the STEM Curriculum Review Framework (herein subsequently referred to as the "SCRF" or the "*Framework*") and the SCRF rubric. The educator guide to the SCRF rubric and the CRT in the STEM classroom are presented separately.

STEM CURRICULUM REVIEW FRAMEWORK: A FRAMEWORK FOR K–12 STEM CURRICULA REVIEW

The Stem Curriculum Review Framework (SCRF) outlines the components needed for a comprehensive review of K–12 STEM curricula. In this paper, "STEM education" and "STEM curricula" refer primarily to integrative instruction that aligns curricula across the Earth and natural sciences, engineering, and mathematics.

The three components of the SCRF provide educators and curricula developers with a context from which to evaluate the quality of K–12 STEM lessons and activities that: 1) align to common standards and across disciplines, 2) employ best instructional practices, and 3) promote learning for all students through culturally responsive teaching.

The *Framework* delivers coherent and focused standards, and teaching strategies on how to deliver content that increases student engagement and success. The following sections describe the three components of the SCRF.

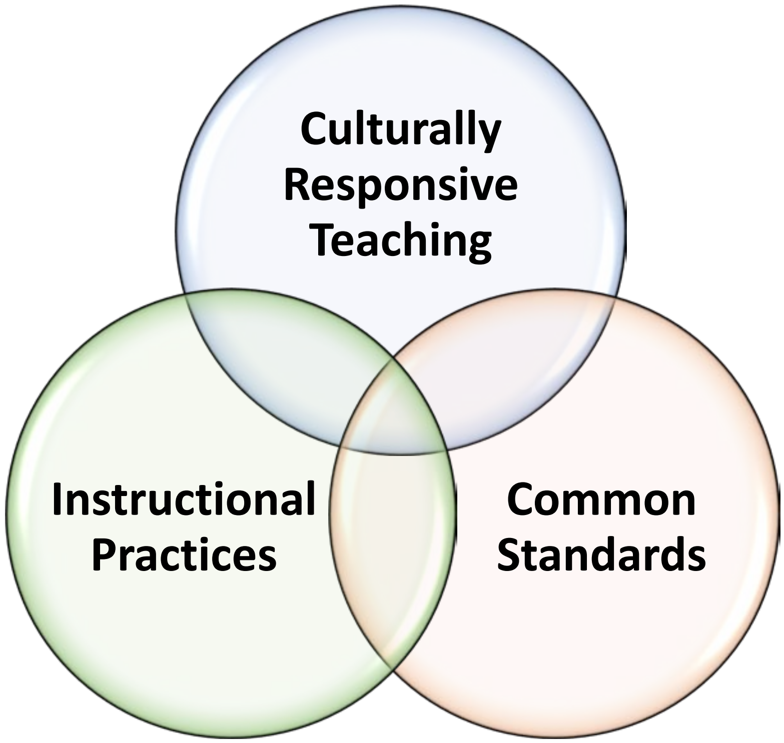

Figure 1: SCRF Conceptual Model

Component 1: Alignment to Standards

Alignment of curricula across disciplines from grades K–12 through the integration of mathematics, science, and the engineering process has been recognized as a way to improve STEM education (Dushl et al., 2007). The Educate to Innovate campaign launched by the Obama administration in 2009 declared that improvement of STEM education will be a national priority in the next 10 years. The campaign highlighted implementation of common standards in both mathematics and science as a means to drive more focused, coherent programs to prepare and support teachers. They would create larger markets for new and more effective instructional materials and technologies, along with high-quality assessments that measure all the important aspects of science learning" (President's Council of Advisors on Science and Technology [PCAST], 2010, pg. 8). The *Common Core State Standards for Mathematics* were released in 2010 followed by the *Next Generation Standards* in 2013. Both standards set grade-specific standards across content domains but do not define how teachers should teach the material (National Governors Association Center for Best Practices, 2010, and Next Generation Science Standards [NGSS], 2013). The "how to" in STEM education has not been operationalized in the past in a comprehensive manner. The SCRF attempts to address this need by including the following two components:

Component 2: Instructional Practices

Instructional practices are teacher/student interactions in the classrooms that are the mechanism through which programs transmit academic, language, and social competencies (Mashburn et al., 2008). There are two kinds of instructional practices, the general (e.g., emotional support) and the content specific (instructional practices) (Mashburn et al., 2008). Both practices have shown to be positively associated with higher academic skills and social competence (Mashburn et al., 2008; Hamre and Pianta, 2005). General instructional practices that differentiate and individualize learning can increase student participation and success by incorporating student choice and providing immediate feedback and assessment (Sotomayor, 2013). Incorporating the elements of collaboration and/or cooperation, attention to intellectual safety, and creating a sense of belonging have been suggested as effective general instructional practices in student learning (Duschl et al., 2007; Huang et al., 2008; Morrison et al., 2008). Furthermore, supporting productive struggle in learning mathematics (Principles of Actions by the National Council of Teachers in Mathematics) and emphasizing scientific argumentation (Frey et al., 2015) are only two examples of effective content-specific instructional practices.

Component 3: Culturally Responsive Teaching

The SCRF uses Gay's (2013) definition of Culturally Responsive Teaching (CRT), which states that CRT is a personal and professional "developmental process" (Gay, 2013, p. 57) that involves "advocacy for teaching to and through cultural diversity to improve the achievement of ethnically diverse students" (Gay, 2013, p. 53). Furthermore, Gay (2010) stated that the purpose of CRT is to empower ethnically diverse students through their "cultural knowledge, prior experiences, frames of reference, and performance styles" for learning to be more relevant to them (Gay, 2010, p. 29).

"CRT" can also refer to Culturally Relevant Teaching, which is sometimes used interchangeably in the literature. "Culturally Relevant Teaching" is a term coined by Gloria Ladson-Billings (1994), and is "a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billings, 1994, p. 17–18). Overall, both terms refer to the need for instruction to strive for academic success for all students with teachers taking action to make connections to the children's cultural experiences to the content.

The literature reviewed appears to indicate that CRT has not been systematically incorporated into STEM curriculum development and review efforts. The SCRF is unique because it incorporates CRT strategically into the *Framework* to recognize its importance in student learning and success.

STEM CURRICULUM REVIEW RUBRIC

The STEM Curriculum Review Framework (SCRF or *Framework*) guided the development of the STEM Curriculum Review (SCR) Rubric. A priority of this work was to operationalize the *Framework* through the development of a tool for educators and curriculum developers to assist them in assessing the quality of STEM curricula. Our research indicates that there have been no attempts in the literature to operationalize Culturally Responsive Teaching (CRT), which is an important contribution to the CRT research agenda.

The following section introduces the SCR Rubric—a tool design for educators and curriculum developers to operationalize effective STEM education that goes beyond a list of best practices by assessing the quality of STEM curricula.

Purpose

The purpose of the STEM Curriculum Review (SCR) Rubric is to operationalize the *Framework* in assessing the quality of STEM curricula.

The rubric provides the reviewer a rating scale of 0 to 2 to evaluate whether or not a specific criterion has been addressed in each component of the SCRF: (1) Alignment to Standards, (2) Instructional Practices, and (3) CRT as follows:

Rating Scale

0 – Criteria is absent in the activity/lesson.

1 – Criteria is present in the activity/lesson, but not adequately, or in a superficial manner.

2 – Criteria is meaningfully and adequately addressed in the activity/lesson.

When a rating of “0” (zero) is assigned, the reviewer is asked to provide suggestions for modifying the activity/lesson to meaningfully address the criteria. If a rating of “1” (one) is assigned, the reviewer is asked to explain why the criteria appears to be inadequate or superficial, and to also include suggestions for modifying the activity/lesson meaningfully address the criteria. If a rating of “2” (two) is assigned, the reviewer is asked to provide a brief explanation justifying this rating. In addition to providing suggestions for improving the event in which the criteria in each rubric component has not been met, the reviewer is asked to provide comments and observations for each component as a whole in a separate document entitled: "SCR Rubric Summary."

STEM Curriculum Review Rubric Summary

After reviewing the activity/lesson, the reviewer fills out the *SCR Rubric Summary* form. This form outlines the three components contained in the SCR Rubric: 1) Alignment to Standards, 2) Instructional Practices, and 3) CRT. To ensure a complete review of the lesson, the 5E Instructional Model description has been included in the SCR Rubric Summary form ("5E" refers to a phase of learning, and each phase component begins with the letter "E"—Engage, Explore, Explain, Elaborate, and Evaluate). The reviewer of the NASA activity/lesson is asked to evaluate whether or not the resource under review is addressing any of the 5E Instructional Model phase components. Suggestions are provided for improving and addressing any missing component of the 5E Instructional Model. For more information on the 5E Instructional Model, refer to ***Addendum A, Overview of the Biological Sciences Curriculum Studies***. The outcome is a document that concisely summarizes the quality of the NASA resource reviewed.

STEM Curriculum Review Culturally Responsive Teaching Addendum and Lesson Update

The SCR CRT Addendum and Lesson Update is a document designed with the practitioner in mind. It summarizes important information (e.g., the common standards addressed in the lesson). For those states with their own standards (e.g., Texas), the curriculum developer can include the subjects and content areas discussed in the resources for the teacher and other practitioners to align the activity or lesson with their own standards.

This document does not include all the components of the *Framework* individually. This form focuses on providing viable recommendations for the teacher for incorporating CRT into the resource. There is also an opportunity to include information on further readings, available educator guides, and any other resource that might be helpful for the practitioner.

Next Steps

The SCRF for STEM curricula quality assessment and enhancement has been implemented in teacher preparation courses across the nation. Improvements continue to be made to the supporting tools and documents. These improvements are based on user feedback to ensure educators and curriculum developers are provided with useful information that is research-based and can assist them in their efforts to enhance STEM instruction for all students.

For more information about NASA EPDC visit https://www.txstate-epdc.net/. For additional information contact: Dr. Araceli Martinez Ortiz, LBJ Institute Executive Director: araceli@txstate.edu.

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APPENDIX A

Overview of the Biological Sciences Curriculum Study 5E Instructional Model

5E Instructional Model

The Biological Sciences Curriculum Study (BSCS) model is a direct descendant of the Atkin and Karplus Learning Cycle used in the early 1960s, and used in Science Curriculum Improvement Studies (SCIS) (Bybee et al., 2006). Since the 1980s, BSCS has used the 5E Instructional Model as a central innovation in elementary, middle, and high school biology; and has been integrated into science programs. The 5E Instructional Model consists of the following phase components: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase component has a specific function that provides a mechanism for the teacher to develop a coherent lesson to help students gain a greater understanding of the concepts being taught.

The 5E Instructional Model builds on the works of other instructional models and is supported by current research on learning. It falls within the theories of a constructivist teaching model (Bybee et al., 2006). Every element of the 5E Instructional Model is carefully crafted to promote a student's construction of knowledge. It further incorporates components of behaviorism and cognitivism models of learning (Jobrack, 2016).

Engagement

The teacher of a curriculum task assesses the learner's prior knowledge and helps them become engaged in a new concept through the use of short activities to promote curiosity and elicit prior knowledge. The activities should make connections between past and present learning experiences, expose prior conceptions, and organize student thinking toward a learning outcome of the current activity. This phase of the lesson provides the teacher with opportunities to find out what students already know, or think they know, about the topic and concepts to be covered.

Clement and Stephens (2008) state there are many ways to activate prior knowledge, including the following:

- Brainstorming
- Questioning and making notation of a student's responses
- Engaging students in a problem or activity to observe what they know

Exploration

Experiences provide students with a common base of activities within which current concepts, processes, and skills are identified; and conceptual change is facilitated. Students may be engaged in lab activities providing the opportunity to use prior knowledge to conduct investigations.

This phase of the model challenges student perception. Mestre (1994) identified four things to consider for students to undergo a conceptual change: 1) the student must have dissatisfaction with a current idea; 2) the student must have minimal understanding of the idea; 3) the student must view the idea as plausible; and, 4) the student must see the idea as useful.

How can a teacher create an environment for the student to engage in exploration? The following is a list of possibilities:

- *Listen to a student discussion to identify misconceptions.*
- *If misconceptions exist, challenge students to identify inconsistencies between their beliefs and scientific phenomena.*
- *Inspire student debate striving to help students identify the consistency with other ideas and phenomena.*
- *Assist students in reconstructing their knowledge.*
- *Engage students in discussion and hands-on activities that challenge their views.*

(Jobrack, 2016)

Explanation

This phase focuses student attention on a particular aspect of their engagement and exploration experiences, and provides opportunities to demonstrate their conceptual understanding, process, skills, or behavior. It is in this phase that teachers can introduce a concept, process, or skill.

In addition, this phase also provides the teacher with an opportunity to include discussion to help students who might have missed the point of the lesson, experienced cognitive overload, or even developed misconceptions (Jobrack, 2016).

Elaboration

Teachers challenge and extend student conceptual understanding and skills. Through new experiences, students develop a deeper and broader understanding, gather more information, and develop adequate skills. Students apply their understanding of the concept by conducting additional activities.

In this phase, the teacher presents new ideas or situations, and encourages students to interact with each other or with resources, including written material, data, web searches, and/or simulations (Bybee, 2009).

Evaluation

The evaluation phase encourages students to assess their understanding and abilities, and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives. In this phase, the teacher should ensure that whatever experiences students have engaged in are relevant to the three prior phases of the model.

Students should also be able to demonstrate knowledge of scientific inquiry. A student should be able to compare their current understanding to their prior knowledge. In addition, after engaging in all phases of the 5E Instructional Model, students in this final phase should be able to ask questions that take them deeper into a concept (Bybee, 2009).

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