Work in Progress – The Development of a K-12 Integrated STEM Observation Protocol

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Dr. Roehrig is a professor of STEM Education at the University of Minnesota. Her research explores issues of professional development for K-12 science teachers, with a focus on beginning teachers and implementation of integrated STEM learning environments. She has received over $30 million in federal and state grants and published over 80 peer-reviewed journal articles and book chapters. She is a former board member of the National Association of Research in Science Teaching and past president of the Association for Science Teacher Education.

Dr. Elizabeth Ring-Whalen, St. Catherine University

Elizabeth A. Ring-Whalen is an Assistant Professor of Education at St. Catherine University in St. Paul, MN. She holds a PhD in Curriculum and Instruction - STEM Education from the University of Minnesota. Her research focuses on STEM education and what this looks like in PreK-12 classrooms and explores teachers' beliefs of integrated STEM as well as how these beliefs influence teachers' practices and student achievement in the classroom. Alongside this research, she has worked to explore the attitudes and beliefs teachers hold about cultural diversity and teaching culturally diverse students. Past and current projects include designing and teaching undergraduate and graduate-level coursework intended to help teachers develop effective science teaching practices and culturally relevant pedagogy for their classrooms, mentoring pre-service science teachers, working with in-service science teachers to develop and implement integrated STEM curricula, leading STEM integration professional development for in-service science teachers, working with administration and teachers to develop STEM programming in their schools, and developing a K-12 STEM observation protocol that can be used in a variety of educational contexts through an online platform.

Jeanna R. Wieselmann, University of Minnesota

Jeanna R. Wieselmann is a Ph.D. Candidate in Curriculum and Instruction and National Science Foundation Graduate Research Fellow at the University of Minnesota. Her research focuses on gender equity in STEM and maintaining elementary girls' interest in STEM through both in-school and out-of-school experiences. She is interested in integrated STEM curriculum development and teacher professional development to support gender-equitable teaching practices.

Dr. Emily Anna Dare, Florida International University

Dr. Emily Dare is an Assistant Professor of Science Education at Florida International University. Previously, she taught at Michigan Technological University from 2015-2018, where she is still an affiliated faculty member in the Department of Cognitive and Learning Sciences. Dr. Dare's research interests are focused on K-12 STEM education. In particular, she is interested in supporting science teachers' reform-based instruction while simultaneously understanding their beliefs. As science classrooms shift to more integrated STEM approaches, this is especially critical. Additionally, Dr. Dare has a passion for working with K-12 students to understand how changes in classroom instruction impacts their attitudes towards and beliefs about STEM fields. In particular, she is looking at 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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Development of a K-12 Integrated STEM Observation Protocol (WIP)

Project Overview

This Work in Progress paper shares the development of an integrated STEM Observation Protocol for use in K-12 science and engineering classrooms. The development of the STEM-OP is guided by our theoretical framework and literature related to the nature of integrated STEM education. The development of the protocol items was followed by exploratory factor analysis using a selection of K-12 integrated STEM classroom videos.

Literature Review

National policy documents in the United States calling for improvements to K-12 STEM Education have been prevalent in the past decade. *Rising Above the Gathering Storm* [1] initiated the current reforms calling for efforts to prepare more students for STEM careers in response to the argument that the continued prosperity and progress in the global market place depend on our ability to prepare the future generation of STEM professionals. The President's Council of Advisors on Science and Technology (PCAST) points to improvements in STEM education as critical in responding to the workforce needs and challenges of the 21st century [2]. The number of STEM jobs is growing three times faster than non-STEM jobs [3], [4] and this may result in a shortage of up to 1 million STEM workers in the United States [2]. In addition to the workforce needs, scientific and technological literacy are increasingly recognized as central to informed decision-making for all individuals living in the 21st century [5]. With the need for a STEM-literate population to fill the increasing number of STEM jobs and make informed personal and societal decisions, preparing students for success in STEM is of unprecedented importance. These calls for improving K-12 STEM education culminated in the *Framework for K-12 Science Education* [6] and the *Next Generation Science Standard*s [7] that put forth new national standards that purposefully and explicitly integrate engineering, technology, and mathematical thinking into science education. Teachers are challenged to provide authentic STEM experiences to students in grades K-12 in order to foster students' engagement and interest in STEM [8].

The problems that we face in our rapidly evolving global society are multidisciplinary in nature, requiring the integration of multiple subjects to develop solutions. The complex and multidisciplinary nature of these real-world problems is a driving force behind arguments for integrated STEM approaches to teaching and learning in K-12 classrooms. Indeed, researchers have argued that integration across the STEM disciplines provide the best opportunity for students to experience authentic learning environments and that teaching without integration "does not reflect the natural interconnectedness of the four STEM components in the real world of research and technology development" [9]. Such approaches not only address student interest in pursuing STEM careers, but also promote the development of 21st Century Skills [10]. However, translating these natural connections between STEM disciplines into curriculum and classroom practices is challenging for teachers [11], [12]. Many teachers are unfamiliar with engineering and STEM approaches advocated in new national and state policy documents and this unfamiliarity is compounded by the lack of agreement on what is meant by integrated STEM education.

Thus, as STEM education moves to an integrated approach in K-12 settings, there is a need to better understand what STEM education is in order to implement it in practice. The literature on STEM education reveals a variety of approaches that include STEM as a replacement term for science and mathematics [13], [14], pedagogical shifts towards an integrated approach [13], [15] [16], [17], curriculum changes that reflect the work of STEM professionals [13], [14], [18], and curricula that emphasize an engineering design challenge [19]. Despite these variations in definitions, there are common elements, including: the inclusion of an engaging, real-world context [13], [20], explicit connections between science, technology, engineering, and mathematics and modeling them as they would be used in STEM careers [15], [16], [17], [21], the intentional development of 21st century competencies [16], [19], and an emphasis of student-centered pedagogies [13], [14], [18], [19].

Need for a STEM Observation Protocol

In addition to the challenge of defining STEM education, there have been challenges in assessing integrated STEM instruction in K-12 classrooms. Given the rapid development of both K-12 engineering and integrated STEM, it is critical that researchers have access to valid and reliable instruments to determine the efficacy of different teaching and curricular approaches related to both teacher effectiveness and student learning. The lack of a protocol designed specifically for such teaching will lead to reliance on the use of teacher self-report data or the use of protocols that measure "just good" teaching without consideration of the nature of the discipline(s) being taught. Existing instruments most commonly used by researchers, such as the Reformed Teaching Observation Protocol (RTOP) [22], were designed prior to the development of the NGSS and were designed for use in reform-based science classrooms, not integrated STEM learning environments. Protocols that measure inquiry-based teaching, such as the RTOP [22], have been used in lieu of a STEM-specific protocol, but these have challenges and limitations [23]. Other existing observation protocols, such as the UTeach Observation Protocol, or UTOP [24], and Classroom Observation Protocol for Undergraduate STEM, or COPUS [25], also focus on one discipline; this is problematic when instruction addresses the integration of multiple STEM disciplines. While the RTOP, UTOP, and COPUS can be used in science and mathematics classrooms, they are not designed to assess lessons that integrate across STEM disciplines or lessons that include engineering. For example, the RTOP includes a single item that assesses the degree to which "Connections with other content disciplines and/or real world phenomena were explored and valued"; similarly, the UTOP gauges the degree to which "Appropriate connections were made to other areas of mathematics or science and/or to other disciplines." However, neither instrument addresses the nature of these connections or defines how a lesson may integrate across such disciplines. This is particularly troublesome when assessing engineering or NGSS-aligned lessons, as the items in these instruments do not directly address scientific practices, engineering practices, or the interplay between science content and these practices.

In order to facilitate the implementation of integrated STEM in K-12 classrooms and the development of the nascent integrated STEM education literature, our research team is developing a new integrated STEM observation protocol for use in K-12 science and engineering classrooms. When complete, this valid and reliable instrument will have been designed for use in a variety of educational contexts and by different education stakeholders to increase the quality of K-12 STEM education and education research. The STEM-OP is intentionally designed not only for summative and evaluative purposes, but also for formative and reflective purposes. The STEM-OP is also designed to work in a range of classroom with the implementation of any STEM curriculum, it is not designed for a specific curriculum or project. At the end of this project, the STEM-OP will be made available through an online platform that will include an embedded training program to facilitate its use throughout the country.

Instrument development process.

In the first year of this four-year project, we have been working on the initial development of the STEM-OP through item development, video analysis, and exploratory factor analysis. We have utilized a selection of existing classroom video from a previous project with approximately 2,000 unique classroom videos representing a variety of grade levels (4-9), science content (life, earth, and physical science), engineering design challenges, and school demographics (urban, suburban). The development of the STEM-OP is guided by published frameworks and other relevant literature that focus on providing quality K-12 integrated STEM and engineering education, such as [6] and [26]. Each item considers a critical characteristic of quality integrated STEM teaching and uses observational data to scale that characteristic on a five-level scale. A sample item is shared in Figure 1. This item addresses a central feature of engineering design thinking, iteration of designs and engaging in re-design, as well as the need for students to explicitly engage in this process to enhance their learning about the nature of engineering.

Students learn through **failure and iteration.**

Description: Students have opportunities to experience failure, reflect on their learning/design process, make revisions to their thinking/design, and learn to tolerate failure as they solve complex problems. This promotes students interpreting failures as opportunities to learn and improve.

0 - The lesson does not provide opportunities for students to learn through failure and iteration, nor does it include opportunities for students to revise their thinking.
1 - The lesson provides opportunities for students to learn through failure and iteration and includes **implicit** opportunities for students to revise their thinking.
2 - The lesson provides opportunities for students to learn through failure and iteration and includes **explicit opportunities for students to revise their thinking**.
3 - The lesson provides opportunities for students to learn through failure and iteration, and the problem solving process (not end product) is emphasized with **opportunities for students to revise their thinking and apply it to solving a problem.**
4 - The lesson provides opportunities for students to learn through failure and iteration, the problem solving process (not end-product) is emphasized with opportunities for students to make revisions to their thinking/design, and **students tolerate failure to persevere in solving complex problems.**

Figure 1: Sample STEM-OP Item

Our anticipated results at the time of the 2019 ASEE meeting will include a review of our item development process and finalized items included on the draft STEM-OP. Additionally, we anticipate being able to share findings from the exploratory factor analysis (EFA) on our video-coded data, which will identify distinct instructional dimensions responsible for integrated STEM instruction. We value the opportunity to gather feedback from the engineering education community as the integration of engineering design and practices is integral to quality integrated STEM instruction.

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