Culturally Relevant STEM (CReST)

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Convergence education, driven by compelling or complex socio-scientific problems, is an approach to bring cultural relevance into secondary STEM education. National trends show the need to increase the STEM workforce by leveraging educational research and innovative practices within the secondary level to increase student interest prior to graduating high school.

Keywords: STEM education ; transdisciplinary learning ; convergence education

1. Introduction

Societal demands on the global workforce display an increasing need for individuals to master science, technology, engineering, and mathematics (STEM) [1]. According to the U.S. National Science Board indicators in 2021, the U.S. STEM workforce includes 16 million workers with an education at the bachelor's degree level and nearly 20 million workers who do not have a bachelor's degree in the skilled technical workforce [2]. For demographic groups, there continues to be an uneven representation in the STEM workforce. This trend seems to be most pronounced for girls and particular non-white ethnic minorities [3][4][5]. Participation in advanced STEM coursework in secondary and higher education, and improvements in facilitating and sustaining STEM interest and participation, particularly amongst those in poor, under-resourced communities, have been at best modest [6]. These are indicators that opportunities to increase the STEM workforce with domestic talent [7] should be a focus on STEM educational research and innovative practices within the secondary level to increase student interest prior to graduating high school.

Convergence education is driven by compelling or complex socio-scientific problems or topics, where learners apply knowledge and skills using a blended approach across multiple disciplines (i.e., transdisciplinary) to create and innovate new solutions [8]. Widya et al. discuss the importance of making connections between what is taught in the STEM classroom and what is occurring in daily life to improve student learning by [9]. Science communities are striving to revise the traditional process of learning where students follow step-by-step procedures to perform a given task to reach a conceptual understanding of the content [10]. The transition from step-by-step labs to a more problem-based and inquiry model represents more of an integrated STEM approach to learning. The integration of engineering design practices into science education allows students to solve relevant real-world challenges that our society faces. The Next Generation Science Standards (NGSS) is committed to leveling engineering design with scientific inquiry within elementary and secondary education [11]. To address these needs, researchers posit a modular, experiential transdisciplinary STEM support curriculum that addresses a global and cultural thread through cultural heritage conservation. Culturally relevant STEM (CReST) is a transdisciplinary learning program that leverages artifacts of cultural heritage as boundary-crossing objects to enable students and teachers to connect key concepts of science, technology, engineering, and mathematics (STEM) to their personal and collective background and experience through convergence education. CReST aims to increase the diversity, equity, and interest of student learners through culturally relevant teaching and structured, hands-on, and transdisciplinary learning.

Through these experiences, students are exposed to artifacts that connect traditionally siloed educational experiences in science, social studies, and engineering in multiple days of instruction. CReST features (1) a convergence educational framework; (2) partnerships with highly visible organizations and institutions providing professional development workshops for participating teachers and career exposure to students; and (3) a strategic global context, focusing on culturally relevant pedagogy, transdisciplinary learning, real-world problem solving, and communities of practice.

2. Transdisciplinary and Convergence Education in STEM

One of the key pathways to provide a more meaningful STEM experience focused on real-world problems is "engaging students where disciplines converge" [12]. Although STEM education fundamentally involves multiple disciplines, the effective approach to the challenge of curricular integration is still unclear. The levels of integration can be differentiated into disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. The highest level of integration is transdisciplinary learning where students apply knowledge from two or more disciplines through real-world examples [13][14]. Transdisciplinary learning can also be framed as convergence education. According to the U.S. Interagency Working Group on Convergence, “convergence education is driven by compelling or complex socio-scientific problems or topics, where learners apply knowledge and skills using a blended approach across multiple disciplines (i.e., transdisciplinary) to create and innovate new solutions” [8] (p. 7).

To investigate the effects of transdisciplinary learning in traditional settings, findings have shown different combinations of disciplines such as social studies and literacy with science and mathematics and physics with biology, which do not have a negative impact on the core subjects within the classroom [15][16]. Strategies to increase student self-efficacy in STEM subjects and career motivation have been pursued through the integration with Arts [16]. To address global issues within classrooms, work has been carried out to shift the learner experience from a passive to an active role.

3. Experiential Learning in STEM

Kolb [17] describes Experiential Learning Theory as grounds for the learner to take knowledge and transform it into an experience within a wide range of situations. The combination of experiential learning with STEM education can assist with helping students not only better understand, but also apply their knowledge to real-world activities. Lestari [18] conducted a quantitative study on increasing problem-solving ability with physics high school students through experiential learning using a STEM approach. The results from a pre/post design showed a high level of student increase in problem-solving ability following the intervention. Long, Yen, and Hanh [19] explored the positive role, from the student perspective, of integrating the engineering design process with the Kolb model in a middle school STEM education setting.

Studies implementing modular STEM learning as a method of enrichment of the traditional curriculum [20][21] have been shown to increase student learning. These studies show a positive correlation to implementing STEM modular lessons within science classes to incorporate more real-world application in the learning experience. Yet, there is still a need to identify both qualitative and quantitative metrics for teacher knowledge, skills, and assessment in order to facilitate STEM modular learning in agreement with the set standards and pace.

4. Culturally Relevant Pedagogy in STEM

The purpose of culturally relevant pedagogy is to empower students [22]. Ladson-Billings [23] proposed that culturally relevant pedagogy should have three main components: academic success and student learning as the focus; the development of cultural competence to assist students’ social identities while also gaining knowledge of other cultures; and skills to identify and solve real-world problems that have resulted in societal inequalities. This theoretical model assists students in acknowledging not only their own cultural identity but also that of others. Young et al. define culturally relevant STEM as “the utilization of cultural funds of knowledge inherent in all learners to develop deep and meaningful connections between STEM content and the learners’ lived experiences” [24].

A multiple-case study was conducted to explore how the implementation of project-based learning through culturally relevant pedagogy in a science class would increase student learning and engagement known as invention-based learning (IBL). The results showed that each participant student required a different amount of content knowledge prior to developing the cognitive ability to transfer that knowledge to real-world situations through a cultural lens. The findings illustrated that knowledge transfer is an “iterative bi-directional process”, not one-way [25].

The Science Genius intervention implemented a qualitative study into ten urban high schools over an academic semester. The schools that participated in this study had students who underperformed, with a lack of interest in science. Science Genius is designed to target disengaged youth through a hip-hop-themed science program. The analysis produced three main themes: (1) the intervention revealed student emotions, (2) students’ raps displayed evidence of essential science content knowledge, and (3) students’ self-science identity was reframed through the intervention. This intervention allowed students to reveal their own thoughts and emotions while simultaneously reframing their own self-identity in the field of science. This research also displayed student evidence of essential science content knowledge [26].

Brown et al. [27] report that culturally relevant teaching remains stationary within STEM education. Some exceptions to this include the workings with hip-hop pedagogy and Science Genius [26][28]. The studies mentioned above showcase how equity pedagogies have been applied into STEM education. Collectively, they utilized qualitative studies with smaller populations to investigate their interventions. Though the overall findings suggest the positive effect of integrating culturally focused pedagogies into STEM, there is still a lack of quantitative research on how this impacts student learning.

5. Intersecting the Four Axes through the Theoretical Framework of CReST

As with the studies discussed above, there is an overall gap in research in terms of quantitative studies. The ability to gather quantitative data concerning student academic learning in alignment with the curriculum within any, or all, of the four areas of STEM would provide better evidence of the impact of the various pedagogical approaches in convergence education and culturally relevant pedagogy in STEM education. As the literature discussed, a common challenge within STEM education is the integration of multiple disciplines. Following the integration of STEM comes the assessment and the challenges of overcoming the traditional model of evaluating student academic success [8]. Lastly, student interest in STEM is of importance and there is an urgency to better meet the workforce demands across the globe. In response to the intersection of these gaps within STEM education, researchers investigated current interactive STEM frameworks as a starting point to develop a theoretical framework that provided a format for convergence education. Leung proposed a pedagogical framework that encompasses connective factors that produce boundary-crossing STEM pedagogy [29]. Leung's formulation of the Interactive Framework for STEM Pedagogy was built from research and findings on the challenges and obstacles an educator runs into as they attempt to cross from one domain in STEM into another. Situated learning, communities of practice, problem-solving, and learning dialogical processes are the four factors of Leung's pedagogy model. Situated learning concerns the cognitive processes of the teacher and student to understand how skills and knowledge can be applied.

Given the nature of the CReST approach to teaching and learning, researchers adapted Leung's Interactive Framework for STEM Pedagogy as a model within both the curriculum development and the assessment of the support curriculum [26]. The framework for CReST leverages cultural heritage artifacts, specifically fresco-style art, as boundary-crossing objects that thread together STEM disciplines through the usage of four factors, namely, Convergence Education, Communities of Practice, Culturally Relevant Pedagogy, and Experiential Learning, as shown in **Figure 1**.

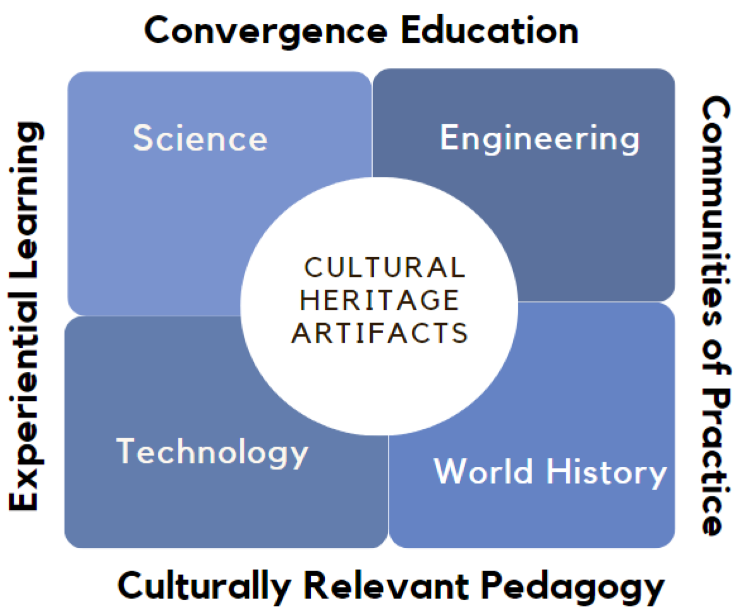

Figure 1. Adapted and modified version of Leung's Interactive Framework for STEM Pedagogy as applied to the CReST curriculum developed by the CReST research team.

The middle terms were modified from the original Leung figure from "boundary object" and "boundary-crossing" to "artifacts of cultural heritage" which is the object used within the CReST curriculum as the boundary-crossing object. The factor Situated Learning was adjusted to Convergence Education, and the other factor, Learning Dialogical Processes, was altered to Culturally Relevant Pedagogy to better align with the CReST curriculum and mission. Problem Solving Processes were adjusted to Experiential Learning. The teachers' community of practice was applied to CReST as the four participants worked together to implement their experiences from professional development.

The artifact of cultural heritage (i.e., frescos) serves as the common theme across the various disciplines to allow time and space for the transfer of knowledge to occur within the classroom. The CReST study used Leung's Interactive Framework for STEM Pedagogy (2020) concept of a boundary-crossing object to serve as the intersection.

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