STEMulate-K12: Automating STEM Attraction

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***Abstract*—This Research-Work-in-Progress presents the development of an e-learning tool that facilitates the integration of science, technology, engineering, and mathematics (STEM) into non-STEM lesson plans. The present effort adds features to promote attraction to STEM. To increase the rate of attracting students to STEM, the researchers are investigating the strategic use of e-learning. The e-learning tool is being designed to be widely accessible online and easily integrated with most K-12 curricula. The tool focuses on enabling students to actively explore the dependencies of STEM-related models without needing to understand the underlying math and science, which is the usual barrier. The researchers previously developed a beta test tool framework for researchers and educators to upload integrated STEM lessons to a shared community of users (K-12 students and teachers). Uploaded lesson materials include a narrative, a representative image, searchable keywords, and a parameterized STEM model. Users can explore various outcomes by dialing-in various input values. This effort advances the prior work by integrating features that are likely to increase attraction to STEM. These features are based on dispelling misconceptions to increase mindfulness and offers guidelines for developing lessons that balance cognitive load and ease. To measure attraction, pre- and post-surveys and statistical analysis will be facilitated through the tool.**

Keywords—STEMulate-K12, attraction, e-learning, STEM integration, online, personalized learning.

I. INTRODUCTION

It is widely agreed that more science, technology, engineering, and mathematics, (STEM) professionals are needed to improve and expand prosperity. However, of the 50 million students enrolled in K-12 in the United States (U.S.), 93% of them do not pursue a STEM degree [1]. Familiarity with STEM will eventually help them make informed decisions about career options, voting on STEM-related policies, and understanding the underlying fundamentals of present and future technologies. To help prepare K-12 children for STEM college and career readiness, a set of science standards was funded by the Carnegie Corporation of New York [2]. The new science standards with a focus on engineering are Next Generation Science Standards (NGSS). Research indicates that principals of engineering can support the acquisition of knowledge and skills that are associated with comprehending and using STEM knowledge to solve real-life problems through design, troubleshooting and data analyses activities [3]. Furthermore, NGSS supports engineering design as a focus or context for learning integrated STEM content, especially applied to real-world problem-solving.

There are several factors that influence or discourage a student's interest in STEM [4]. Some influencers include an integrated approach to teaching math or science, mentorship, motivational activities, self-efficacy, curriculum guidance, and countering socioeconomic detractors. Since the overarching goal of the tool is to help increase the proportion of K-12 students that attain a high interest in STEM, many of the factors that influence a student's attraction to STEM are being automated in the tool.

Section II discusses prior work in the areas of STEM attraction and describes a prototype of STEMulate-K12. Section III proposes how attraction and its assessment can be automated with an e-learning tool such as STEMulate-K12.

II. BACKGROUND

A. STEM Attraction

There are several barriers to attracting students' interests in STEM. This paper focuses on a few of the most significant barriers identified as designated major STEM attractors [6-9], such as an adequate integrated approach to teaching STEM; a constellation of motivation strategies, self-efficacy, situated interest, and expectancy-value through mentoring; and countering socioeconomic detractors.

STEM Integration: A 2013 study reported on the shortage of teachers who are adequately prepared to teach integrated STEM content and practices, which historically have been excluded from K-12 teacher preparation [10]. Another study reported on the urgent need for further research and discussion on the knowledge and experiences that teachers need to effectively teach integrated STEM content in the classrooms [11]. Further emphasize is placed on teachers being prepared to teach integrated STEM considering that integrated STEM content, when taught appropriately, focuses on principles and practices that promote engineering ways of thinking, learning, and doing; teachers are not only tasked with teaching integrated STEM content, teachers are also tasked with teaching students to use integrated STEM knowledge to solve real-world problems through modeling, design, and data analytic activities.

Mentoring: Another obstacle to STEM attraction is the lack of a constellation of mentoring strategies that address social, instrumental, cultural and community relevant support, and curriculum guides that most students require to develop STEM content knowledge [12]. Several studies have documented the positive impact that STEM intervention programs have on attracting students to STEM. These programs typically offer a

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variety of contextualized support including cultural and community relevant mentoring, tutoring, and academic advising, and can mean the difference between those students that obtain that support which fosters STEM attraction and no support at all [13-15]. Little to no work has been done on virtual mentorship.

Socioeconomic Detractors: Socioeconomic detractors are quite subjective from student to student. Such detractors often include instructors that are culturally insensitive or are not able to integrate STEM into their lesson plans. Such detractors disproportionally affect low socioeconomic areas, often lack proactive academic counseling, and lack a community of relevant persons or industrial connections to STEM [16].

B. *STEMulate-K12*

STEMulate-K12 is being developed as a K-12-friendly virtual lab to promote STEM-thinking. K-12 students will be able to control a variety of realistic STEM experiments without instruction from teachers. This attribute is expected to facilitate an integrated use in non-STEM lesson plans. This idea is illustrated in Figure 1, where a student is using STEMulate-K12 during a history lecture about ancient Egypt to figure out how many years it would take to build a pyramid of the desired height.

Figure 1: Depiction of an instructor integrating a STEMulate-K12 lesson into a non-STEM History lesson about ancient Egypt.

Young people are natural-explorers, often learning by trial and error. STEMulate-K12 leverages off this learning process by presenting explorative STEM environments as playgrounds. The tool is designed to support situated cognition as described by Brown, Collins, & Duguid, where concepts are best learned when they are situated and consistently developed through activity [4]. As research suggests, the tool is designed to scaffold learners across a range of domains [5]. Several tiered scaffolding approaches are achieved by communicating problem-solving strategies, coaching users with hints and reminders, use of models, and facilitating a library for users to access examples of prior problem solutions.

STEM educators will be able to upload new lessons into a library that all users will have access to. To contribute a STEM lesson to the community, an instructor will upload lesson specifications such as estimated grade level, subject matter, a text description of the STEM lesson, images and or videos, bounded input parameters that students will use to explore the lesson, and the modeling equations. See Figure 2a.

The graphical user interface (GUI) consists of areas for images or video, a text description of the problem, bounded sliders for exploring input parameters, and output results. For instance, Figure 2b shows an agricultural life science STEM lesson for possible crop development on Mars. Although the underlying model involves mathematical relationships that may be beyond the educational level of the young learner, the bounded sliders enable students to understand how the results depend on input parameters. This method of exploration effectively mimics how scientific experiments are done, where analyses test the sensitivities of each control parameter on the result to develop deeper understandings and predictive models.

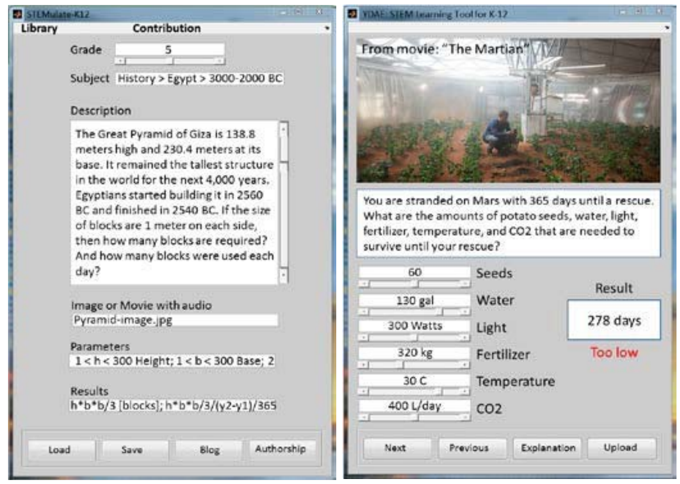

Figure 2: (a) How lessons are uploaded into STEMulate-K12's library. (b) Agricultural life science lesson on growing potatoes on Mars.

III. AUTOMATION

STEM integration: The automated approach to integrated STEM content rest on the three tenets of teaching STEM integrated content proposed by Vasquez, Sneider, and Comer, which are multidisciplinary, interdisciplinary, and transdisciplinary [17]. Multidisciplinary involves coordinated lessons from several subjects that emphasize connections across the subjects. Interdisciplinary involves concepts from two or more subjects that support each other. And transdisciplinary involves reflection of students' interests and questions. For instance, the lesson depicted in Figure 1 involves aspects of each. It integrates the subjects of history, geometry, and construction engineering; the model is supported by geometry and construction, and the subject's context allows students to explore and reflect on the planning that went into this historic event.

Formative assessment is achieved by having the STEM lesson provide immediate feedback results to the student's input parameters. Such immediate self-assessment allows students to adjust their answers as they explore and seek to understand the STEM lesson. For summative assessment, results from each student's performance will be stored. Such information can be compared to other students in the class or all students that have used a particular lesson.

Mentorship: Mentorship activities will be guided through user-customizable avatars, which will provide help, advice, and links to real-person videos. Avatars will be used to answer frequency asked questions, guide students through lesson modules, and motivational coaching. Videos from persons of all ages will be used to provide mentorship to students regarding academic and career paths, overcoming adversities, study habits, balancing academics with non-academic activities, meeting goals, life planning, etc. Avatar assistance can be deactivated.

The tool's mentorship features will be assessed through ranked survey questions regarding self-efficacy and motivation, and suggestions for improvements or new topics to cover.

Countering socioeconomic detractors: Methods used to counter low socioeconomic detractors will involve STEM-integrated lessons and mentorship activities that focus on relevant and tangible topics of interest to underserved areas or situations. The lessons will educate the students on the STEM in their daily lives, including the technology involved in creating their particular styles of music, shoes, sports, clothes, cars, cell phones, food supply, etc. Lessons will also include ways that STEM can be used to improve the quality of their environment, prosperity, and future career paths. Regarding mentorship, videos of STEM professionals that spent their childhood in low socioeconomic areas and other adverse conditions will discuss overcoming their hardships, misconceptions, stereotypes, and lack of preparedness to become successful and an important contributor to society. Information will also be provided about STEM events, scholarships, learning opportunities, etc., which are often available but not well-communicated to the community in which such programs were designed to serve.

IV. SUMMARY

This work-in-progress outlines the features that are proposed for an e-learning tool that facilitates the integration of STEM into non-STEM lesson plans to promote attraction to STEM. Further testing and design development are needed. The objective of the tool is to facilitate a culturally relevant environment where students can develop problem-solving skills by making connections between STEM subjects, non-STEM subjects, and everyday things.

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