DEPICT: Discovering Computational Thinking in Creative Writing Courses

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Abstract: How can you connect the work of Computer Science (CS) with an innovative literary work? How can educational research develop multiple junctures, where students engage in Computational Thinking in ways that reflect their skills and interests? These are the type of questions that DEPICT (Discover Computational Thinking through Creative Writing) sets out to answer. The DEPICT project investigates a novel intervention to broaden participation in computing of underrepresented and minority populations. It exposes concepts of Computational Thinking (CT) within the existing curriculum of high school Creative Writing courses. Through the redesign of lectures and activities of a non-STEM discipline, DEPICT measures how the infusion of CT impacts student and teacher outcomes while enhancing the learning of the host discipline and to what extent the infusion of CT enhances interest in CS studies and careers for traditionally underrepresented students.

Keywords: Computational thinking, creative writing, Computer Science education, technology integration

Introduction

The focus of this project is to investigate the impact of using a class of a non-STEM discipline that is popular among the target population—i.e., Creative Writing (CW)—as a vehicle to provide high school students with competence in Computational Thinking (CT) while enhancing the learning of the host discipline. DEPICT aims to generate and disseminate knowledge about these practices by studying the impact of the project activities on student and teacher outcomes. As part of this work, the research team collected and analyzed data to determine the impact of infusing CT in CW. The overarching research question explored by this project is: "How do K12 and University research teams create, implement, and refine pathways within CW toward computational learning across the curricula to promote broadening participation in computing?"

The novelty of DEPICT lies in two aspects. First, DEPICT builds on an area that has not been deeply explored, i.e., the combination of creative writing and CT. The appeal of this area comes from its popularity among students, especially women and Hispanic students, and the high level of self-efficacy demonstrated by students in the corresponding courses. The second novelty comes from the use of this creative domain as a target for the infusion of CT; we use CT as a methodology to teach the creative domain, contending that relevant concepts of CT are already present in the domain, and they simply need to be extrapolated to provide students with an understanding that spans both human creativity and the formality of machines. The project incorporates a novel perspective, and it detaches from previous approaches, where the domain discipline is usually utilized as a target for technological applications of computing.

DEPICT introduces a collaborative model, fostering the development of high school teaching and Computer Science (CS) learning teams that build on each member's expertise and attributes while delineating clear paths for new memberships. The foundation of the team structure is the creation of teaching triads, composed of a high school teacher, one undergraduate CS student, and one graduate CS student. Teaching triads are designed to leverage varied perspectives to the curriculum and classroom practice of CT where teachers are engaged in the development process, and graduate and undergraduate students contribute to the activities associated with the infusion of CT in the curricula.

Theoretical or Conceptual Framework

DEPICT draws on a sociocultural theory of learning called Cognitive Apprenticeship (Cole, 1998) to create new frameworks that enhance teaching capacity in CT within Creative Writing (CW) courses. Cognitive Apprenticeship (CA) is a model of instruction that works to make thinking visible. This form of thinking out loud does not necessarily come naturally to the experts but can be enhanced through training and practice in CA. The Cognitive Apprenticeship will be operationalized through: (1) Modeling (Rogoff, 1990), which occurs when more competent others (e.g., graduate students) demonstrate expert practice for learners (e.g., high school students); (2) Coaching involves expert practitioners giving feedback to learners as they explore the discipline (Lave and Wenger, 1991); (3) Articulation is the explicit communication of one's thought processes (Lampert, 1990; Salomon, 1997) (e.g., through module portfolios).

The second theory of importance to DEPICT is systemic organizational change. DEPICT utilizes Coburn's theory of change (Coburn, 2003) to promote organizational change, through a shift in ownership, the spread of innovation, depth of implementation, and sustainability. DEPICT addresses these concepts by exploring innovative pedagogical modules to infuse CT in CW (and connecting such modules to relevant standards) and establishing an expectation of teachers to assume a role in the professional development of other teachers and ambassadorship for CT and computing as a core skill within all disciplines.

Rationale/Significance of the Study to the Field of Teacher Education

Computing and K12 Education

Code.org (2021) reports over 400,000 open computing jobs, with about 71,000 CS graduates entering the workforce. The insufficient number of students pursuing CS can be attributed to a variety of factors, but a critical reason lies in the CS gaps in the K12 system. While other countries have enhanced their educational efforts in computing (Powell, 2019), the CS Teachers Association (CSTA) reports neglect of CS at the high school level in the U.S. Only 47% of all high schools offer any CS curricula and only 19 states require high schools to teach CS. In the southwestern state where this research is taking place, only 32% of the schools offer CS content, with only 21% offering AP CS courses; in 2020, only 371 students took an AP CS test, with less than 25% being female. Such lack of high school preparation in CS is a threat to the number of students pursuing CS college degrees: exposure to computing before college is a critical motivation towards the pursuit of CS degrees (Stephenson, 2011).

Women and Hispanics in Computing

While the intention of Hispanic students to earn a college degree is similar to national averages for all students, only 22% of Hispanic students who enter elementary school will complete college, compared to 39% of all students (Excelencia in Education, 2016). The situation is worse if we focus on CS. According to CRA (Zweben and Bizot, 2021), Hispanic students account for only 8.5% of all computing bachelor's degrees, a far cry from parity (about 18%).

The underrepresentation of women in CS is well-documented (NCWIT, 2020). The problem has deep roots in the academic pipeline; 57% of AP tests are taken by women, but only 31% of the AP CS test are taken by women; 57% of undergraduate degrees are of women, but only 21% of CS degrees earned by women (NCWIT, 2020; Zweben and Bizot, 2021). New Image for Computing (WGBH Educational and ACM, 2009) reports that college-bound women are largely less interested in CS than men—this is also related to the fact that sex-role stereotypes are formed early, particularly for "gender-appropriate" occupations (Guss and Adams, 1998). The situation is worse for Hispanic women; 2% of women in computing jobs are Hispanic (7% Asian; 3% African American).

Infusing CT in Arts & Humanities

The idea of infusing CT in non-STEM curricula is an effective way to introduce new students to computing. It simplifies the illustration of CT, contextualizing it through domain-inspired problems and linking computing to topics that are relevant to the student in the class. The process of infusing CT into a targeted discipline has also benefits for such discipline. The infusion helps students in constructing mental representations of issues being studied (e.g., the structure of a narrative), facilitating inquiry-based learning and exploratory analysis (Gunstone and Mitchell, 1998; Ryokai, et al., 2003). Effective pedagogy requires structured educational materials, mechanisms to develop an adequate level of automaticity, and well-supported instructional environments. CT and its modeling strategies (Dalton, et al., 2002; Plass, et al., 1998) are excellent instruments to achieve this (Jonassen, 2003; Gilbert, 1998). CT enables reasoning at different levels of abstraction and emphasizes the transition from using the information to creating knowledge.

Implementation

DEPICT is currently operating in a southwestern district, in two diverse high schools with a minority enrollment of 84% and 80% of the student body [majority Hispanic] in both cases. DEPICT expected goals are (1) Provide CT exposure to high school teachers and diverse groups of students that would, most likely, not consider computing as an option; (2) Provide teachers with preparation, pedagogy, and curricula to instrument students with CT problem-solving tools and skills that can further advance the students' competency and performance in the host discipline (e.g., creative writing) and in future learning experiences; (3) Generate new research knowledge about the benefits of infusing CT in high school arts and humanities courses to promote broader participation in computing.

Providing CT exposure to non-computing population. DEPICT aims to introduce the basic concepts of CT (i.e., decomposition, pattern recognition, algorithmic thinking, abstraction, sequence, and repetitions in algorithmic design, etc.). The learning triads put together activities that are part of a regular CW lesson where students and teachers explore how these concepts relate to daily tasks such as creating a recipe for a poem, finding similarities within different micro-fiction pieces to come up with a new self-original micro-fiction piece, exploring how an Ernest Hemingway poem "Hills Like White Elephants" conveys abstraction of social topics like abortion in a very subtle writing style, or being able to create a writing prompt that asks others the instructions (algorithm) to write a poem or a freewriting

piece (Fig. 1). Many high school students in the DEPICT program are students who don't see themselves in a computing field, either because they struggle with any STEM-related class or because they see CS as a difficult subject. By embedding CT concepts into the core humanities courses they already know or are familiar with, DEPICT distills new ways to approach a future inclination for the CS field.

Figure 1. Examples of Computational Thinking concept mapping for Creative Writing lessons

Topic	CT/CS related topic
Zen Koans (paradoxical puzzle)	Propositional Logic
Looking at patterns	Abstraction
Concrete nouns/ Connotation/Denotation	Variables
Describe a flavor/ Random Imagery	Random Numbers
Collaborative poem	Paired programming
You are a mirror. Write to your human self.	Time capsule/storytelling
Write a story about an event. Use "But", "yet", "however" to switch the second part of the story	If-Else Conditionals

Providing CT problem-solving skills to further learning. The CT exposure process includes modifying lectures and class activities to emphasize the use of CT concepts to explain creative writing content. For instance, as part of the course's content, students learn about the Rashomon effect, a storytelling and writing method, in which an event or scene is given contradictory interpretations or descriptions by the individuals involved. DEPICT exposes one of the AP College CT Practices (College Board, 2020), the computational solution design while learning the Rashomon effect with the use of a hands-on digital learning platform called Merge Cube (Fig. 2), where students use the platform to create 3D objects and simulations on each side of the cube to describe different interpretations of their story. DEPICT uses the host discipline as the context to explain how CT works and uses CT to enhance the learning of the host discipline.

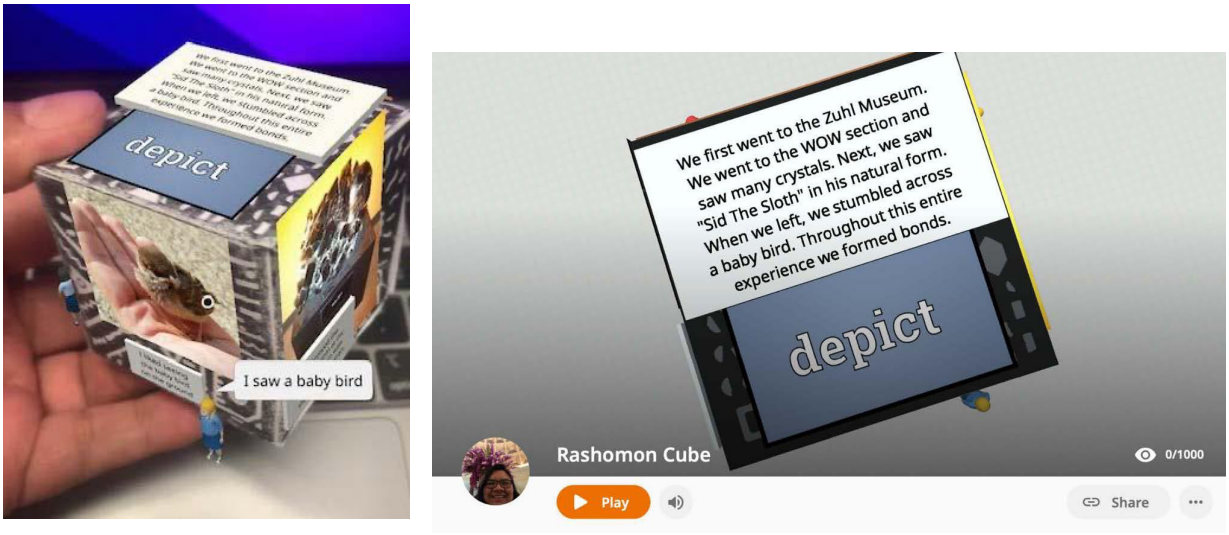

Figure 2. One of the activities that students created during DEPICT implementation was the use of the tech tool, Merge Cube, to create an original piece of their own story with its four different versions on each side of the cube, that can be visualized using augmented reality.

Generate new knowledge to broaden participation in computing. DEPICT was implemented during the 2022-2023 academic calendar in two CW classes. Although lessons and activities were designed pre-implementation, the research team understands that every class is different, and activities must be modified for each classroom. The main idea of the program is to use teachers' expertise from the host discipline to unveil how CT connects with CW, in order to discover how students' way of thinking and creativity are prompted as a result of the CT infusion, and how two different ways of thinking (CT and CW) work together to enhance learning that promotes problem-solving skills that can be used in any discipline.

Scholarly Significance

By targeting language and arts-dominant courses for infusion of CT, DEPICT aims to broaden the appeal of computing to students who may not consider themselves as belonging to a technical field. Bringing creative and artistic design into the curriculum may also redefine who is "right for" the field, through the development of complementary STEM pathways that are appealing to a group of students adept at arts, language, and theater. Regarding pedagogy, the program will solidify a strong network of educational collaborations between the research team and local high schools creating a human infrastructure of teachers in the Arts and Humanities competent in CT.

Conclusion

DEPICT aims to infuse CT in domains where there is evidence of strong motivation to participate by women and students from underrepresented groups in CS and uses CT as an instrument for teaching the target discipline. The infusion of the CT concepts provides DEPICT with a deeper exposure, opportunities for reinforcement, and coordination among related courses. DEPICT also jump-starts the development of the CS educator community by establishing cohorts, researchers, and other members of the local educational district to share experiences, ideas, and discussion topics relevant to the teaching of CT. We expect the DEPICT learning community to become a self-sustaining collaborative network, to support research and teaching in developing CT infusions.

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