Exploring Non-Scientific Disciplines as a K-12 Vehicle to Carry Computational Thinking: An Agenda

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Introduction
The U.S. is experiencing a dangerous paradox. U.S. has achieved a world dominant role in computing, led by the innovative a spirit of the U.S. economy and supported by strong Computer Science (CS) academic programs. Yet, this competitive position is vacillating and we are facing the risk of losing scientific leadership, due to sheer lack of trained workforce. The CRA reports a decline in undergraduate CS majors of more than 60% since 2000 [17], and the 2009 numbers from the Higher Education Research Institute show percentages as low as 1% of freshmen with interest in CS.

The underrepresentation of women in CS is also well-documented. [1] reports that, while 58% of professionals in the workforce are women, this number is only 25% in computing. The problem has roots that grow deep in the academic pipeline; 56% of AP tests are taken by women, but only 19% of the AP CS are taken by women; 57% of undergraduate degrees are of women, but only 18% of CS degrees are of women (2009)—down from 37% in 1985 [17]. New Image for Computing [16] reports that college-bound females are largely less interested in CS than boys (10% rates it a good college choice)—this is also related to the fact that sex-role stereotypes are formed early, particularly for gender-appropriate occupations. The situation is worse for Hispanic women; 1% of women in computing occupations is Hispanic (4% Asian; 2% African American). Hispanic women earned 1.6% of CS bachelors degrees in 2006, with only 0.03% of Hispanic female freshmen interested in CS, the lowest of all STEM disciplines. There is a strong association in the Hispanic community of careers and genders; families support girls in entering fields not linked to male preferences (e.g., to not threaten the “es muy macho” status)—leading Hispanic girls away from CS [14]. A career in CS is painted by images of solitary white men at the computer; these do not meet the desire of support and collaboration expected by Hispanic girls.

Hypothesis
Our research objective is to explore, research, and deploy novel interventions to broaden participation in computing of Hispanic high school students, with special focus on female students. The guiding principles of our recent work and of our hypotheses is the
importance of **infusion** of *Computational Thinking (CT)* in the context of the general high school curricula. Infusion implies exposing the concepts of CT as integral components of existing disciplines, thus achieving training in CT as part of non-CS curricular activities; CT becomes a natural instrument to explain the target domain [15]. The strength of such approach is the possibility of discovering and reinforcing CT outside of the realm of traditional science; in particular, our interest is in the use of *creative writing* and other aspects of *developing and producing movies* as the main vehicles for the CT infusion. With some abuse of terminology, we refer to such target curricula (*creative writing, screenplay and storyboard, production of stage plays and movies*) as *Performance and Creative Writing (PCW)*.

**Why infusing CT?**
The idea of exposing students to computing through infusion of CT in non-CS curricula has been explored before, and shown to be an effective way to provide broad exposure of students to critical learning skills. There are conceptual and practical reasons for this line of work. Placing CT in the context of a domain has immediate benefits to the teaching of computing. It simplifies the illustration of CT, contextualizing it through domain-inspired problems. Infusion of CT provides anchoring of the principles and practices of CT by identifying the need for them within the target domain. Finally, it demonstrates the relevance of computing by tying it to topics that are relevant and appealing to the student. The process of infusing CT into a target discipline has also benefits to such discipline. (1) The infusion helps students in constructing mental representations of issues being studied (e.g., the structure of a narrative, a scientific observation), facilitating inquiry-based learning, exploratory analysis and providing structure to the domain [9]. (2) Effective pedagogy requires well-designed educational materials, mechanisms to develop an adequate level of automaticity, and well-supported instructional environments; CT and its modeling strategies (e.g., emphasis on processes and context building) are excellent instruments to achieve this [8]. CT enables reasoning at different levels of abstraction, and emphasizes the transition from using information to creating knowledge. CT is not necessarily tied to programming, but it is a way to conceptualize problems, situations, processes, and the whole range of issues associated to problem-solving (e.g., what steps solve a problem? What makes a solution better? What makes a problem difficult?).

From a practical perspective, CT infusion addresses the limitations of K-12 school curricula and systems that are stretched in terms of time and resources and cannot easily accommodate new computing courses. For example, in the Southern New Mexico area in which we operate, none of our partner school districts offer regular CS courses (beyond application oriented courses or keyboarding). Where available, computing courses tend to be unpopular electives, with enrollment that is low and very skewed in terms of gender and ethnicity.

**Why infusing in Creative Writing, Theatre and Movie Production?**
The target domain for the infusion that we are currently exploring is the creative foundation for the development of movies/plays, covering the aspects of writing, composition, production, and deployment of a story on a stage or in a film. There are various reasons for this choice.
Many authors have explored infusion of CT in STEM domains; this type of infusion is natural, and the benefit to STEM learning obvious. Nevertheless, such an approach may not lead to broadening participation in computing; we are often dealing with students that are struggling with the complexity of science and math, and they are deterred from such disciplines to start with; thus, we need to face the compound problem of attracting students to STEM and engaging them in computing (both carrying preconceived attitudes). CT infusion in STEM disciplines may detract time and flexibility in the exploration of CT within the discipline; the curricula itself is often more rigid. We prefer to pursue infusion in domains that are perceived by the students as “easier”, where students do not have negative attitudes, and offering adequate curricula flexibility. Additionally, we want to infuse CT in domains where there is already evidence of strong motivation to participate and learn by Hispanic students; such evidence is still lacking in most STEM disciplines, while it is significantly more evident in the PCW domains; this is the result of several factors, including greater teachers’ confidence, greater presence of role models, more opportunities for social engagement and sense of belonging, and more obvious support for affective engagement [7,4].

We also want to infuse in a domain that is exciting to the students; while the infusion in areas like robotics or gaming could be exciting (though some authors are questioning that), it might be impractical to have elective courses on such topics; our aim is to maximize impact by infusing CT in core courses that are relatively simpler for students or existing electives that are popular among the target population. Enrollment statistics [and anecdotal reports from local schools indicate that students tend to take more credits in English than other disciplines (often with higher achievement than in STEM); in New Mexico, English language composition and English literature composition are the most popular AP exams; they are also the second and fourth most popular AP exams for Hispanic students (no STEM exam makes the top 5). There is also evidence that improved writing skills affect access to postsecondary education [12].

Last but not least, we hypothesize that a significant matrix of CT skills and abilities (covering, for example, a large part of CSPriniciles learning objectives) can be elegantly introduced in PCW courses, where CT concepts are often used (e.g., Venn diagrams, semantic networks, rules, recursive processes of refinement, algorithmic-like descriptions of styles) but not explicitly recognized.

**Why infusing CT for Women and Hispanic students?**

The literature [11] suggests that women tend to perceive the importance of computing not as a self-sustaining discipline, but in the broad context of serving the needs of other disciplines and to address societal needs. Additionally, the literature on Hispanics in CS has underlined the importance of recognizing the cultural diversity of students in the way curricula are designed; Hispanic students tend to thrive in curricula that recognize their history, culture, relevant role models for self-identification—e.g., 95% of AP Spanish Literature test takers in New Mexico are Hispanics. These aspects indicate the benefits of exploring computing conceptualized in other disciplines [2], where it can be connected to areas of relevance to the students (e.g., arts, media), with references to problems affecting society. The infusion in domains that can be linked to the Hispanic culture will, in turn, break the cycle of apathy and low achievement, and promote sustainable interest [6].
Infusion of CT in a non-STEM discipline wants to counterbalance the preconceptions and negative attitude that surround computing. Several researchers have reported preconceived attitudes as critical factors in deterring women from the field of computing. The general lack of awareness of scientific information among minority students creates also an aura of mystery and confusion surrounding computing as a career option; even though Hispanic students tend to express interest in science, they also do not perceive themselves as scientists. On the other hand, such negative attitudes are not evident in disciplines related to PCW. Women demonstrate high confidence and self-efficacy in PCW—there is a stereotypical view of writing as being a female domain, and liberal arts and public service are common choices of college majors especially for minority women. Furthermore, even though Hispanic males tend to underperform in writing/composition w.r.t. women, they demonstrate a comparable level of self-efficacy as their female peers. This is a powerful argument in favor of infusing CT in PCW: it allows us to capture Hispanic and female students at high levels of self-efficacy and confidence; considering that self-efficacy correlates to academic achievements [13], this offers us an avenue to leverage self-efficacy in PCW to build self-efficacy in CT, away from negative preconceptions.

Researchers have studied the most effective teaching models for Hispanic students. [5] shows the importance of sociological models—peer-oriented (better suited to Hispanic females) or structured team learning (better for Hispanic males). Other researchers have investigated the importance of cooperative and group-oriented pedagogical models (e.g., peer-oriented and kinesthetic models), showing their importance for field dependent students; Hudgens argues that Hispanic students are more field dependent than other ethnic groups [10]. Such collaborative learning styles and holistic perspectives, in line with how Hispanic students acquire knowledge, are not common in STEM teaching; they are instead frequently used in PCW courses (e.g., in studio-based learning). Since the infusion of CT in PCW follows the pedagogical structures of the host discipline, this enables us to more effectively expose Hispanic students to CT.

From a practical perspective, PCW courses are offered at the collaborating schools at full capacity each semester (30-40 students per course), and the demographics of such courses reflect a high participation of women (more than 50%) and Hispanic students (from as low as 70% to as high as 98%).

**Challenges and Opportunities**

While the idea of combining CT with Arts and Humanities has been touched before, the exploration of CT within the context of creative writing and the creative aspects of developing a screenplay is a relatively novel approach that has never been fully developed and formally assessed and evaluated.

On one hand, this approach provides is great opportunities: (1) This approach has the potential of becoming a good instrument to broaden participation in computing: PCW courses offer access to a large and diverse audience, without preconceived negative attitudes and with a great degree of self-efficacy; they also enable to connect the CT infusion with the students’ creative exploration of their own cultural, historical, and family backgrounds; (2) The CT infusion combines the creative aspects of computing with the creative aspects of writing & performing arts; the emphasis on creativity is a critical
component of engagement of students (who are not self-selected students interested in computing) and to progressively build their CT self-efficacy.

The process of infusion we envision represents a transition from the traditional contextualization of CT (i.e., the demonstration of CT as application within a contextual domain, leading to an independent computing-oriented curricula), often found in the literature, to a process of conceptualization of CT within the target domain—where CT is an integral component of such domain. We conjecture this approach will leverage the students’ self-efficacy in PCW to build self-efficacy in CT, reducing the leap to gain CT competence.

At the same time, there are significant challenges to explore this avenue of research: (1) To becomes successful, this type of intervention should articulate a coordinated set of courses, allowing a progressive reinforcement of CT skills, and providing a non-STEM pathway towards more formal CS training, such as the upcoming AP CS Principles curriculum. (2) The transition from infusion to formal CS requires a collection of bridge activities that are probably outside the scope of PCW curricula (e.g., through informal learning activities). (3) Assessing acquisition of CT competency and self-efficacy within a PCS curricula is an unexplored challenge; assessment instruments within PCW curricula are inadequate to capture CT; traditional instruments for CT assessment are hard to introduce in PCW without defeating the overall benefits of infusion (e.g., without forcing students to return to formal and technical materials). Last but not least, the assessment of competence in CT is still a largely open issue.

References


