Food for Thought: Supporting African American Women's Computational Algorithmic Thinking in an Intro CS Course

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ABSTRACT

African American women who have little if any experience in computer programming prior to matriculation into college often struggle in introductory CS courses that emphasize programming from the outset. These same students feel underprepared and disadvantaged, oftentimes choosing to withdraw from such courses which contributes to the underrepresentation of African American women in CS. The challenge lies in creating equitable learning environments that bridge students' everyday experiences to fundamental CS concepts. In this experience report, we introduce *the Dessert Wars Challenge*, an alternative pedagogical strategy that leverages students' everyday experiences with food to forge meaningful connections to CS. We examine how African American women's participation in the *Dessert Wars Challenge* supports the development of their Computational Algorithmic Thinking (CAT) capabilities, the ability to design, implement, assess and adapt algorithms, and contributes to their retention in a college-level introductory CS course.

CCS CONCEPTS

• Social and professional topics ~ Computer Science Education

KEYWORDS: African American women; computational algorithmic thinking; food

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1 INTRODUCTION

Prior research demonstrates that one of the obstacles in increasing the representation of women in Computer Science (CS) is their lack of experience in computer programming prior to matriculation into college [1, 8]. The lack of prior programming experience is acutely relevant to underrepresented populations due to the lack of exposure and access to computing resources in K-12 education [11]. Such lack of experience creates inequitable learning environments in which underrepresented populations (i.e., African American women) struggle to achieve academically, resulting in decreased retention of such populations in CS higher education.

While many African American women enter college with little if any CS-related experiences, cooking and food touch the lives of every individual in every culture and from every walk of life [16]. All students have funds of knowledge or everyday experiences with eating or preparing food, ranging from the simple act of fixing a bowl of cereal for breakfast to cooking a main entrée for dinner [13]. Leveraging students' funds of knowledge about food, we seek to create equity, equal access to resources and learning opportunities for all students regardless of their prior knowledge or experiences, in the CS classroom setting. Hence, we introduce the *It's All in the Mix* module, a series of food-focused activities that bridge students' every day experiences with food to Computational Algorithmic Thinking (CAT)---the ability to design, implement, and assess the design and implementation of algorithms to solve a broad range of problems [16-17, 23, 25]. CAT makes explicit a critical aspect of computational thinking through its focus on understanding how learners identify and understand a problem, articulate an algorithm or set of algorithms in the form of a solution to the problem, and evaluate the solution based on some set of criteria [23, 25-27].

In this experience report, we focus on one specific food-related activity within the module---the *Dessert Wars Challenge*, and how it supports student development of CAT capabilities in an introductory CS course offered on an all-women Historically Black college campus. Our research explores the following questions: 1. What are African American women's perceptions of the *Dessert Wars Challenge* learning activity? 2. How does participation in the *Dessert Wars Challenge* support students' developing CAT capabilities? This experience report makes three contributions. First, building upon existing CS education research, we leverage students' funds of knowledge [13] about food as the context for African American women to develop their CAT capabilities in an introductory CS course. Second, we demonstrate that the integration of CS unplugged activities into introductory CS courses creates a level playing field for all students to succeed, thereby increasing the retention of African American women.

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Third, we outline the implications for creating equitable learning experiences for underrepresented populations.

2 MOTIVATION

Our research is motivated by two factors: 1. the need to increase the representation of African American women in computing; and 2. leveraging students' everyday experiences with food as the context for Computational Algorithmic Thinking (CAT).

2.1 AFRICAN AMERICAN WOMEN IN CS

Statistics show that the percentage of African American women receiving Bachelor's degrees in CS has significantly dropped over a ten-year period (2004 – 2014) even though the enrollment in CS courses at the college level has increased in recent years [14, 29]. Multiple strategies have been employed to increase the participation of African American women in the field of CS. For example, Dahlberg et al. [7] broaden participation in CS via the STARS Alliance, a network of CS programs sponsored on multiple university/college campuses in the U.S. that target African American undergraduate students. Scott & White [22] embed culturally responsive pedagogy into CS curriculum to empower African American middle school girls to utilize technology to fight social injustices. Thomas [23] examines the longitudinal development of CAT capabilities in African American middle school girls as they learn how to create multiple video games for different platforms. However, less research has specifically emphasized the inclusion of equity as a key component in the design of learning experiences that retain African American women in CS.

2.2 FOOD AS THE CONTEXT FOR CAT

Computational Algorithmic Thinking (CAT) focuses specifically on the process of designing, articulating, implementing, adapting, and discarding algorithms as needed to determine the "right" solution to a problem [23, 25]. The introductory CS course featured in our study emphasizes CAT to support students' understanding of what CS is and how computer scientists approach and solve problems in a step-by-step, logical, and creative manner. Most importantly, the course intentionally introduces algorithms as a precursor to programming, creating a level playing field for students who may not have any prior programming experience [8].

One area in which students have prior, though tacit, knowledge of algorithms is in the context of using a recipe to prepare a dish. Prior research demonstrates that cooking and baking activities can provide an effective context for helping students to develop scientific reasoning skills [3, 10, 19]. Because cooking, eating, and engaging with food are common experiences that cut across culture, race, age, and socio-economic status, students have funds of knowledge---ways of knowing of, talking about, and interacting with food in their everyday experiences---that we intentionally draw upon in the classroom setting [13]. These funds of knowledge allow us to leverage students' everyday experiences with food as the context for students to develop their CAT capabilities [2, 16, 17].

Leveraging Schneider & Gersting's [20] definition of an algorithm---a set of well-ordered and unambiguous instructions that are feasibly computable and halt in a finite amount of time, we utilize food as a bridge to CS for several reasons. First, recipes represent a specific set of ordered instructions inclusive of specific ingredients, their corresponding amounts and the specific order in which ingredients are mixed together and manipulated (e.g., baked in an oven) to create the final dish. Second, writing a recipe represents the process of designing an algorithm. Third, following a recipe to prepare a dish models the act of implementing an algorithm. Fourth, the result, an edible dish, represents the output of the algorithm while tasting the dish is indicative of algorithm assessment. Finally, cooking requires the element of creativity, something that students often mistakenly think is undervalued in CS. The goal is to bridge students' funds of knowledge about food to CAT development in an entry level CS college course.

3 DESSERT WARS CHALLENGE

Inspired by popular reality TV cooking shows, we have developed the *It's All in the Mix* module as part of a college-level introductory CS course. This course satisfies the CS requirement for STEM majors and is the first CS course in the curriculum for CS majors. *It's All in the Mix* currently consists of a set of integrated food-focused activities---*Peanut Butter and Jelly Sandwich*, *Dessert Wars Challenge*, and Make My Dish---that expose students to CAT through the design, implementation, assessment, and adaptation of recipes [8,14,16-17]. For the purposes of this paper, we specifically focus on the *Dessert Wars Challenge* because this challenge emphasizes the role of creativity in algorithm design. Students work together to create unique desserts using a variety of available ingredients. The learning objectives are: 1. to collaboratively write a well-defined recipe for a unique dessert based upon a set of ingredients; and 2. to collaboratively create a unique dessert using the set of available ingredients.

3.1 SETTING & PARTICIPANTS

The introductory CS course was offered at a Historically Black liberal arts women's college in the southeastern United States. Thirty-five African American women enrolled in the CS course - 24 during Spring 2015 and 11 during Spring 2016. All 35 women signed IRB to participate in the *Dessert Wars Challenge*. The same instructor taught both course sections. During the first week of classes in both sections, students completed a survey to measure their prior knowledge of CS concepts and prior computer programming experience. More than 80% of the students did not understand how to design, implement or evaluate algorithms as a problem-solving technique nor did they have any prior experience writing code.

3.2 SPRING 2015 INTRO TO CS COURSE

For the first enactment of the *Dessert Wars Challenge* in Spring 2015, students were divided into teams of 4-5 students. A variety of ingredients, including yogurt, blackberries, strawberries, blueberries, sliced almonds, chopped walnuts, pecan chips, chocolate syrup, caramel topping, whipped cream, and vanilla wafers along with bowls, napkins, and plastic utensils were placed on a table. Each team was given 5 minutes to view the ingredients and brainstorm about ideas for creating a unique dessert and 10 minutes to select the ingredients to make their desserts and write the corresponding recipe for their concoctions. Teams were free to use any or as much of the ingredients on the table with no further instructions about making their desserts. After 10 minutes, each team presented their dessert and corresponding recipe to be judged by the teaching assistants. Each team received feedback about their dessert based on presentation, originality, documented recipe, and taste. The instructor facilitated a class discussion about the similarities (e.g., use of same ingredients) and the differences (e.g., layering of ingredients, etc.) of each of the recipes and how these differences exemplified the role of creativity in algorithm design. Leveraging reflective practice [20] as a tool for learning, students completed an online journal entry after the activity.

3.3 SPRING 2016 INTRO TO CS COURSE

For the second enactment in Spring 2016, the instructor modified the *Dessert Wars Challenge* based upon student feedback received in Spring 2015. The food-related activity took place in an on-campus kitchen lab space consisting of a stove, refrigerator, oven, and plenty of counter top/work spaces. Eleven students self-selected their team members, resulting in 5 teams of 2-3 students each. The instructor provided explicit instructions about the required components for creating the unique dessert. Each team was required to choose ingredients that represented each component of the dessert: 1. dessert base---short cake or vanilla wafers; 2. filling---vanilla yogurt, strawberry yogurt or whip cream; 3. fruit---raspberries, strawberries, or blueberries, or pineapple chunks; 4. Nuts---sliced almonds, pecan chips, or walnut pieces; and 5. toppings---chocolate syrup, caramel or whip cream. All ingredients were separated per team and placed in different work spaces designated for each team. Paper bowls and plates, plastic cutlery, and napkins as well as extra ingredients were placed on the kitchen counter. Each team was allowed 5 minutes to view the selection of ingredients and 15 minutes to write and execute a recipe of the team's unique dessert. Each team then placed the final creation of their desserts on a serving table. Next, teams turned in their recipes of their desserts before randomly being assigned to create another's team dessert. The result was then placed next to the original dessert and using the criteria of presentation, originality, documented recipe, and taste, evaluated by the instructor and teaching assistants. The instructor led a group discussion that compared the similarities and differences in the two implementations of each team's dessert, asking students to assess any differences of the two desserts and what attributed to those differences while highlighting characteristics of well-defined algorithms. Finally, students completed their online reflective journals to capture their impressions of the food-focused activity.

3.4 DATA COLLECTION AND ANALYSIS

We intentionally chose to utilize self-reflection journals to capture students' perceptions of their learning experiences in their own words to empower their voices to be heard. This was terribly important to the authors since African American women in CS are often characterized by numerical data under the heading "women of color" (which only tells half of the story), or they are rendered invisible under the assumingly homogenous category of gender [12,15,29]. To assist students with their journal entries, we prompted them to answer the following questions: 1. What was easy about the *Dessert Wars Challenge*? 2. What was difficult about the *Dessert Wars Challenge*? 3. What suggestions do you have for improving this learning activity? 4. What did you learn about algorithms as a result of participating in the *Dessert Wars Challenge*? 5. Would you recommend the *Dessert Wars Challenge* as a required activity for this course? Using SurveyMonkey, we collected online reflective journal entries for the *Dessert Wars Challenge* in both sections and imported entries into NVivo. Content analysis was performed over the full set of students' responses to identify categories of emergent themes for each question. For example, similar student responses to the question "What was difficult about the *Dessert Wars Challenge*?" were grouped together (i.e., "The most difficult part was making a dish that was creative," "It was difficult to create an intricate dessert," "Being creative so our dessert wasn't like everyone else's," etc.) based upon similar phrases and meaning to identify the categorical theme of creating a unique dessert. Using this same process for questions 1 – 4, we identified 15 emergent themes for the category of ***easy***, 11 emergent themes for the category of ***difficult***, and 13 emergent themes for the category of ***suggestions***.

Because the initial focus was on the design of the food-focused learning activity in Spring 2015, we gauged the impact of student participation in the *Dessert Wars Challenge* on their algorithm design capabilities in the Spring 2016 semester. All 11 students in the Spring 2016 course section were given the following test question for evaluation: Write an algorithm that gets the price for item A plus the quantity purchased of each item. The algorithm prints the total costs of all items purchased, including a 6% sales tax. Using Schneider & Gersting's [19] definition of an algorithm, we derived the following rubric to evaluate students' test answers: 1. The algorithm must include ordered steps; 2. The algorithm must get the price and quantity of item as inputs; 3. The algorithm must include primitive operations, conditional statements or repetitive statements; 4. The algorithm must correctly calculate the total price inclusive of the 6% tax; 5. The algorithm must explicitly halt in a finite amount of time (e.g., final step of stop). Using the predefined rubric, two raters separately coded students' test answers and then discussed and resolved differences to achieve 90% inter-rater reliability.

4 RESULTS

We analyzed students' online reflective journals for both course sections and assessed students' responses to the test question below.

4.1 SPRING 2015 STUDENT REFLECTIONS

Students identified several easy concepts as a result of participating in the *Dessert Wars Challenge*. We identified 8 emergent themes for the category of ***easy*** (e.g., choosing the ingredients, creating the dessert, writing the recipe/algorithm, etc.). Fifty percent (12 students) thought it was easy to be creative, the dominant emergent category. See Table 1. This suggested that the variety in the selection of ingredients and working collaboratively promoted thinking outside the box. For example, one student asked permission to leave the classroom to go get popsicle sticks to help her teammates to create a unique presentation of their dessert, giving them a competitive edge. Twenty-five percent (6 students) identified the second dominant emergent category of ***easy*** to be writing the recipe/algorithm. This suggested that working together as a team made it easier to write and execute the recipe in a short timeframe.

We identified 5 emergent themes for the category of ***difficult*** (e.g., the act of being creative, incorporating different operations into a recipe, logistical problems encountered during the food-related activity, etc.). Seventy-one percent of students identified the dominant category of ***difficult*** to be logistics for enacting the food-related activity. See Table 1. Students indicated that the time constraints, limited amount of ingredients, insufficient workspace and number of students in one group made it difficult for them to complete the activity. Time became the contributing factor as students had to manage their time wisely while they worked together to brainstorm ideas for their desserts and then simultaneously write the recipe while making the dessert with whatever ingredients were still available at the time of implementation. Teams that quickly figured out and agreed upon which to dessert to make had the advantage of access to the entire selection of ingredients while some groups had access to only a limited set of ingredients due to spending more time on planning.

We identified 9 emergent themes for ***suggestions*** (e.g., more structure for the food-related activity, more variety and amount of ingredients, student selected team members, creating more desserts, etc.). When asked how we could improve the *Dessert Wars Challenge*, students made several recommendations: 1. Give teams more time to really think about what dessert they want to create and sufficient time to do so; 2. Create a separate, designated workspace for each team so that students are not on top of each other as they work together to create their desserts; 3. Separate the ingredients and supplies per team so that each team has the same selection and amount of ingredients and supplies; and 4. Provide more structure/instructions for the food-related activity; 5. Allow teams to select their own members. Based upon student feedback, the instructor re-designed the food-related activity.

4.2 SPRING 2016 STUDENT REFLECTIONS

We had slightly different results for the category of ***easy*** in the Spring 2016 enactment of the *Dessert Wars Challenge*, identifying 7 emergent themes. Sixty-four percent (7 students) identified logistics for enacting the food-related activity as the dominant ***easy*** category. Students indicated that the re-design of this activity better facilitated students' ability to carry out the different tasks of brainstorming, writing the recipe, making the dessert and then using another team's recipe to make the second dessert. Because of the small sample size (N=11), no more than 2 students reported any other tasks as being easy.

While we identified 6 emergent themes for the category of ***difficult***, five of those themes were reported by no more than 18% (2 students). The dominant emergent theme of ***difficulty*** was time constraint. However, this theme was reported by only 27% (3 students), suggesting that majority of students had sufficient time to construct their dessert.

Between Spring 2015 and Spring 2016, the instructor re-designed the *Dessert Wars Challenge* informed by 2015 student feedback. For example, the instructor made sure that the learning activity took place in the on-campus kitchen lab which had plenty of workspace for each team to maneuver as they worked together to create a unique dessert. Each team also had a selection of the same amount and variety of ingredients so that no team had the advantage over another team. Consequently, we identified only 4 emergent themes for ***suggestions*** (i.e., more variety of ingredients, more time, more rules and no suggestions) with students reporting fewer logistical problems and more satisfaction with the food-related activity. Sixty-four percent (7 students) in the Spring 2016 course made no suggestions for improving the food-related activity and thought it was well structured. Only 2 students suggested using typical ingredients for desserts indicating that some students were not familiar with desserts that included some of the ingredients (e.g., sliced almonds). (Note: the total percentage for Spring 2016 equals more than 100% because students made multiple suggestions.)

Table 1: Comparison of Course Enactments

	Spring 2015 (N=24)	Spring 2016 (N=11)
Easy Tasks	-Being creative (50%) -Writing the recipe (25%)	Logistics for enacting food activity (64%)
Difficult Tasks	Logistics for enacting food activity (71%)	Time constraint (27%)
Suggestions	-More time -Larger workspace -More ingredients -Same amount of ingredients per team -Self-selected teams -More structure	-Fine as is -Use typical dessert ingredients

4.3 SELF-REPORTED LEARNING OUTCOMES

Because we had such a small sample size in each course section, we combined students' online journal entries for both enactments to identify emergent themes for the category of ***self-reported learning***. We identified 11 unique emergent themes for both course sections. Fifty-four (54%) (19 students) self-reported the dominant emergent theme of learning how to apply the characteristics of well-written algorithms. Students revealed that they had a better understanding of the characteristics of well-constructed algorithms, citing the use of clear, organized and precise instructions as a requirement for writing algorithms. Fourteen percent (5 students) identified the second dominant emergent theme of self-reported learning to be creativity (e.g., "I learned that the construction of an algorithm can greatly affect the outputs of a problem…that the inputs given can be the same, but with different algorithms the results will vary."). This supports the potential of the *Dessert Wars Challenge* to promote creativity while utilizing students' implicit knowledge of recipes to develop new funds of knowledge of algorithms as creative problem-solving tools [13].

4.4 ALGORITHMIC DESIGN

The question remained as to whether the *Dessert Wars Challenge* provided adequate support to assist African American undergraduate women with algorithm design in an academic setting. We gauged the impact of student participation in the *Dessert Wars Challenge* on their ability to design algorithms in the Spring 2016 semester. The majority demonstrated the ability to write well-defined algorithms. Using the rubric defined in the previous section (i.e., ordered steps, halts in finite amount of time, etc.), we coded all 11 students' answers to the cash register problem. Fifty-five percent (6 students) received full credit for their algorithm while the remaining 45% received partial credit. All 11 students wrote algorithms that consisted of primitive operations (e.g., Set variable Price to X.XX). Nine percent (1 student) included a conditional statement in her algorithm because she created her algorithm as a flow chart, suggesting that she preferred flow charts to pseudocode when designing algorithms. Ninety-one percent (10 students) accepted price and quantity of an item as inputs and correctly calculated the total price including the 6% sales tax. Only 27% (3 students) did not order their steps nor did they include a halt statement in their algorithms.

5 PUTTING THE PIECES TOGETHER

The *Dessert Wars Challenge* has revealed several insights for designing equitable learning experiences in CS when teaching underrepresented populations such as African American women.

5.1 STUDENTS' DEVELOPING CAT CAPABILITIES

Based upon students' feedback, the *Dessert Wars Challenge* did provide sufficient motivation and a situated context for African American women to develop their CAT capabilities, specifically their ability to design and implement algorithms. Using a Likert scale from 1 (strongly disagree) to 5 (strongly agree), 89% (31 students) recommended that we keep this food activity as a required part of the introductory CS course. Though students perceived the time constraint to inhibit creativity, the teams rose to the challenge and created unique desserts using the predetermined selection of ingredients. Students successfully articulated algorithms in two different contexts---first, as recipes of desserts which are exemplars of algorithms and second, as a solution to the cashier problem mentioned above. A few students even created real life scenarios (i.e., "Bill wants to buy 6 basketballs for $10 each.") to situate their algorithmic solutions. Students' ability to perform both activities confirmed previous research which explored the potential of food-related activities to serve as a bridge between students' tacit knowledge of algorithms in the context of recipes and their explicit knowledge of the design and implementation of algorithms as a problem-solving tool in an academic setting [20]. Furthermore, qualitative analysis of students' online reflective journals suggested that students thought critically about the characteristics of a well-defined algorithm and developed skills to write precise and organized algorithms with little if any ambiguity. One student wrote, "I learned that an algorithm must be written out in a manner so the algorithm can be executed exactly. This is where being unambiguous comes into play." Such evidence emphasizes the potential of the *Dessert Wars Challenge* to support students' developing CAT capabilities.

5.2 RETAINING AFRICAN AMERICAN WOMEN

Comparing the percentage of students who completed the Spring 2015 course to the percentage of students who completed the Spring 2016 course, we had retention rate of 96% (lost 1 student due to health issues) and a retention rate of 100%, respectively, even when students did not have passing grades at midterm. When comparing the retention rate for both course sections to the same introductory CS course taught in Spring 2017 by the same instructor but without the inclusion of the food-related activities, we saw a decreased retention rate of 79% with poor academically performing students dropping the class at midterms. We posited that 21% (7 students out of the initial enrollment of 33 students) dropped the class because more instructional time was spent on learning how to write Python code in the first few weeks of the course with less time allocated for extending students' funds of knowledge to their understanding of the concept of algorithms, how to design them and the correlation between algorithmic design and programming. Anecdotally, students in the 2017 course complained about the fast pace of the course as they struggled with the programming concepts, especially since most of the students had no programming experience prior to taking the introductory CS course.

In comparison to predominantly White institutions (PWIs), 100% of students enrolled in all three sections of the introductory CS course were African American women. Furthermore, the all-women's southern liberal arts institution and the classroom environment embodied inclusion and challenged the status quo of African American women not representing a critical mass of the STEM student population. In addition, the instructor shared the same ethnicity, gender and life experiences as her students, positioning the instructor to be a role model to other African American women in STEM and CS. Thus, the initial starting point in the course represented a level playing field, since the young women were not a minority nor were they subject to a hostile learning environment that conveyed the message that African American women do not belong in CS. This course also elevated and honored the intersectional experiences of these students, being both African American and female in a Computing space, which is also rare in STEM [5,6,24]. Additionally, the instructor also willingly relinquished some of her power as the instructor to welcome an opportunity for students to criticize her pedagogical strategy, an act of inclusion and an invitation for joint ownership which engaged the African American women as co-designers in creating a more equitable learning experience. These situational factors constituted a more equitable learning environment than most CS departments at PWIs. However, without the inclusion of *It's All in the Mix* even in this nurturing learning environment, retention of African American women in introductory CS courses still presented quite a challenge.

5.3 LIMITATIONS OF THE STUDY

Due to the small sample size (N=35), we cannot generalize our preliminary findings. One future research goal is to compare the CAT capabilities of larger student populations who engage in the *Dessert Wars Challenge* with those who do not, exploring ways to scaffold students' CAT capability development. Because food serves as the context for CAT capability development, it is not clear if we would see similar retention rates if we were to conduct the same study with African American undergraduate students of both sexes. We plan to explore gender differences in retention rates and learning outcomes in future research.

6 CONCLUSION

In summary, effective pedagogical strategies which target African American women are crucial to the retention of this population in CS. This paper describes an alternative pedagogical approach that leverages African American women's everyday experiences with food to develop their CAT capabilities in a college level introductory CS course. Integration of food-related activities creates an equitable learning experience, increasing student retention in the college-level introductory CS course.

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