DISSECT: Exploring the Relationship Between Computational Thinking and English Literature in K-12 Curricula

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Abstract—DISSECT (DIScover SciEnce through Computational Thinking) is a project aimed at introducing students to computer science principles by establishing computational thinking (CT) as a problem-solving technique within middle school and high school Science, Technology, Engineering, and Mathematics (STEM) courses. While DISSECT has shown successful integration of CT into middle school and high school STEM curricula, illustrating the pervasive nature of CT, a question remained; "can CT also be infused into humanities courses (e.g., English, Art, History) in addition to scientific courses (e.g., Chemistry, Biology, Computer Science)?" The answer is positive. The objective of this paper is to present one approach to bridge the gap between CT and humanities through the curriculum of a 12th-grade English Literature course. The course blends CT practices with composition and literature to provide students with the ability to write critical and comparative analyses of selected literature. This paper will describe multiple modules that integrate computational thinking into the course, and discuss the results and assessment tools used to measure student competency in computational thinking.

Keywords—Computer science; Computer science education; Computational thinking; English literature; K-12

I. INTRODUCTION

Despite the ubiquity of electronic devices, the majority of the students who use them don't understand the underlying technology (i.e., how the device actually works). This may be attributed to the lack of computer science (CS) courses in K-12 education; Code.org reports [1], "the majority of schools don't even offer computer programming classes," and only 25 states allow CS to count toward high school graduation math or science credits. Additionally, College Board presents data [2] that shows a low participation in the Advanced Placement (AP) CS Exam. Further, there aren't enough qualified CS teachers because the CS teacher certification is "typified by confounding processes and illogical procedures" [3].

Because CS is deeply rooted in daily life, it is essential to provide all students and teachers with the knowledge needed to succeed in a computing world. The National Center for Women & Information Technology explains that present and future innovation require students to not only be computer-literate, but to possess the design, logical reasoning, and problem solving skills inherent to CS [4]. According to the Association for Computing Machinery [5], there are several reasons to study CS including: CS is a pervasive science that provides necessary 21st century skills, enables people to solve complex problems, offers many types of lucrative careers, and offers opportunities for creativity and innovation.

DISSECT (DIScovering SciEnce through Computational Thinking) is a project aimed at introducing students to computational thinking (CT) as a problem-solving technique within middle school and high school Science, Technology, Engineering, and Mathematics (STEM) courses. Traditionally, the underlying concepts of CT including algorithmic design, reasoning with abstraction, and problem formulation and decomposition are taught within a CS course. DISSECT operates under the premise that these concepts are also fundamental in scientific disciplines, and hypothesizes that CT can also be discovered within non-scientific disciplines. DISSECT expects that by infusing and explicitly teaching CT within the context of non-computing disciplines, students benefit from pedagogy that enhances the learning and simultaneously provides a foundation for the principles and practices of CT. In the rest of this paper, we summarize DISSECT's program design, describe modules that have integrated CT into a 12th grade Literature course, and present the assessment tools and results of the project.

II. PROGRAM DESIGN

A. Program Organization

The organization of DISSECT can be represented by a two-pronged approach. First, as indicated above, DISSECT builds upon the idea that CT is already embedded in the curricula of many disciplines, and can be made explicit; this enables a wider use of CT within curricula and enables students to understand CT. Second, DISSECT builds on a model that pairs graduate students (fellows) from computing-related disciplines with a middle school or high school teacher; each fellow-teacher team collaboratively conduct CT activities and the discovery of CT within the curricula. The ultimate benefit of this pairing model is the cross training that occurs between the teacher and fellow. While the fellow provides the CT expertise, the teacher offers effective K-12 pedagogies. This is key, because typically fellows do not have formal teaching experience and most teachers have not been trained in CT or

have not explicitly incorporated CT into their curricula. In particular, fellows will leave DISSECT with better communication skills, increased teaching abilities, and a deeper understanding of the relationship between the teacher's subject matter and CT. The teachers will acquire knowledge and practices of CT, and have access to CT modules that can be applied to their classrooms when fellows are no longer present.

DISSECT currently staffs one full-time coordinator; ten fellows from computing-related disciplines including CS, Electrical Engineering, Horticulture, and Agricultural Biology; and nine teachers from the Las Cruces Public Schools (LCPS) district in a wide range of classrooms including CS, Science, Zoology, Chemistry, Forensic Science, Biology, and English Literature.

B. Curriculum Design

CT is the "thought process involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" [6]. In 2006, Jeanette Wing argued [7] that CT is "a fundamental skill for everyone, not just computer scientists." This statement launched a debate among educators, researchers, and computer scientists about the instruction, application, and integration of CT into other disciplines. The curricula DISSECT develops and uses to introduce CT into K-12 classrooms is composed of a series of modules that aim to portray CT within the context of the course. Building upon the characterization of CT by the Computer Science Teachers Association [8] and College Board's AP Computer Science Principles [9], DISSECT builds on and integrates the following ten concepts into their modules. An *algorithm* is a process or sequence of steps to be followed to solve a problem. A *sequence of steps* is an ordered list of instructions. *Branching* involves a choice in an algorithm that leads to a different outcome depending on the choice. *Iteration* is the repetition of instructions. *Variables* are named pieces of data used by an algorithm that are subject to change. *Clarity* is an algorithm's quality of being certain or easy to understand. *Correctness* is the measure of reliability of the result of an algorithm or sequence of steps. The algorithm is correct if it produces the correct solution to the problem being solved. *Efficiency* is a measure of the performance of an algorithm. When compared to longer algorithms, shorter algorithms that produce the same solution are more efficient. *Abstraction* is the process of removing unnecessary information in order to keep the parts that are relevant to the problem. It is used to simplify the process of achieving a desired goal. Finally, *computational thinking* is a way of solving problems that involves reasoning with abstraction and thinking algorithmically.

In general, the fellow and teacher take one of two approaches to integrate CT into their course. The most common approach is to utilize existing course units and restructure the related activities to explicitly highlight CT concepts. As an alternate approach, the fellow-teacher team may choose a CT concept to highlight and then create a module that relates to both the course discipline and the CT concept.

III. IMPLEMENTATION: ENGLISH + CT

While DISSECT has shown successful integration of CT into middle school and high school STEM curricula [10], illustrating the pervasive nature of CT, DISSECT wanted to determine whether or not CT concepts (algorithms, sequence of steps, branching, iteration, variables, clarity, correctness, efficiency, and abstraction) could be integrated into a 12th grade English Literature course (ENG12). In particular, the choice of ENG12 was to reach students who did not have pre-conceived positive attitudes toward STEM or explicit experience with CT; generally, students are intimidated by math and science, thus CT may also induce a sense of fear. On the other hand, students tend to have a positive attitude toward arts and humanities (at the very least, they aren't scared of those subjects); this allowed DISSECT to explore and teach CT in a context that is less frightening and without preconceived notions.

The following sections describe the goals of ENG12 and modules that show the seamless integration of CT into the teaching of Literature.

A. English 12

The study has been conducted during the Spring 2014 (SP14), Fall 2014 (FA14), and Spring 2015 (SP15) semesters on three ENG 12 courses taught by Timothy Staley at Onate High School (OHS) in Las Cruces, New Mexico. Staley also taught two additional sections of ENG12 in Spring 2014 which will be referred to as "Control Class 1 (CC1)" and "Control Class 2 (CC2)" throughout this paper; neither control class was taught any modules that featured or explicitly introduced the DISSECT CT concepts. As a whole, the classes utilized the collaborative tools and services provided by Google's suite of Apps for Education [11].

The OHS Curriculum Guide [12] describes ENG12 as a course that "blends composition and literature into a cohesive whole as students write critical and comparative analyses of selected literature to… develop and improve critical thinking and analytical skills." Over the course of the class, students are introduced to, and tested on, the New Mexico Content Standards with Benchmarks and Performance Standards for English Language Arts [13]. Students enrolled in ENG12 are required to take the Literature End of Course Examination (EOCE) that tasks students to: 1) answer multiple-choice questions by thinking critically and 2) write an essay that demonstrates their ability to follow directions and their knowledge of the usage of literary elements in pieces of literature. The EOCE serves as a final exam for ENG12, and student scores are reported to Staley, OHS, and Las Cruces Public Schools district for various purposes [14] including "student grades, curriculum reviews, student graduation requirements, and for the Educator Effectiveness System."

In order to meet the course objectives and to prepare students for the EOCE, Staley's ENG12 courses were comprised of four units to enhance student analyses of four main pieces of literature: Lord of the Flies [15], song lyrics, Macbeth [16], and Siddhartha [17].

B. Unit Modules + CT

The existing ENG12 unit modules were enhanced to allow students to practice CT skills. Ensuring the content of the course remained consistent was an important design constraint during the integration of CT. A summary of each ENG12 unit module and its relation to CT is provided in the following sections.

Lord of the Flies: The Lord of the Flies (LOF) is a novel about a group of boys that are stranded on an island with no adult supervision. The major theme explored is the inevitability of chaos and loss of civilization when the boys are faced with the barbaric nature of the wilderness. This theme was mainly conveyed through the author's use of symbols. Symbols are objects, characters, and figures that are used to represent an abstract idea or concept. One of the goals of ENG12 is to teach students how to identify symbols and explain in a multi-paragraph essay how the symbols developed through the entire piece of literature.

CT was integrated into this unit through the LOF Symbol Development project by having students work collaboratively on a single Google Document to find every instance of eight symbols in the novel, and then forming groups to write a one-paragraph summary of the development of a symbol. In particular, this module was designed to provide students a collaborative avenue to learn and practice abstraction, a necessary skill for success on the writing portion of the EOCE.

For example, after a group of students identified the 125+ instances of "conch", a symbol representing societal order, they used abstraction to summarize the development of the conch:

"In the beginning of the novel, Piggy finds a conch near him and Ralph in the water. The conch starts off as a way to get everybody who is on the island together, and is used as a talking stick, whoever holds it has the right to speak uninterrupted. This started out well, because all of the children followed suit. That is until Piggy held the conch; he was the one person who they'd disregard and ignore while Ralph was the only one trying to enforce the rule. After some time, the children started to ignore the call to assemble when the conch was blown. This represented the beginning of the loss of order. By the end of the novel, total chaos ensues when Roger drops a large boulder on Piggy, killing him and smashing the conch into a million pieces. All order was lost and there was no going back to civilization."

Song Lyrics: By nature, song lyrics are full of poetic devices. This unit aimed to teach students how to identify elements of poetry (e.g., rhyme, repetition, etc.) in shorter pieces of literature (i.e., song lyrics).

The CT aspect of this unit centered on the Song Lyric Analysis Site. Students worked in pairs to complete the four components of the project: lyric analysis, poetry device data analysis, song critique, and website creation. A Google Document was used to annotate the song lyrics; a Google Spreadsheet was used to chart and analyze the amount of music and figurative language elements; Internet sources were used to garner peer-reviewed song reviews; and Google Sites was used to compile their analyses into a website.
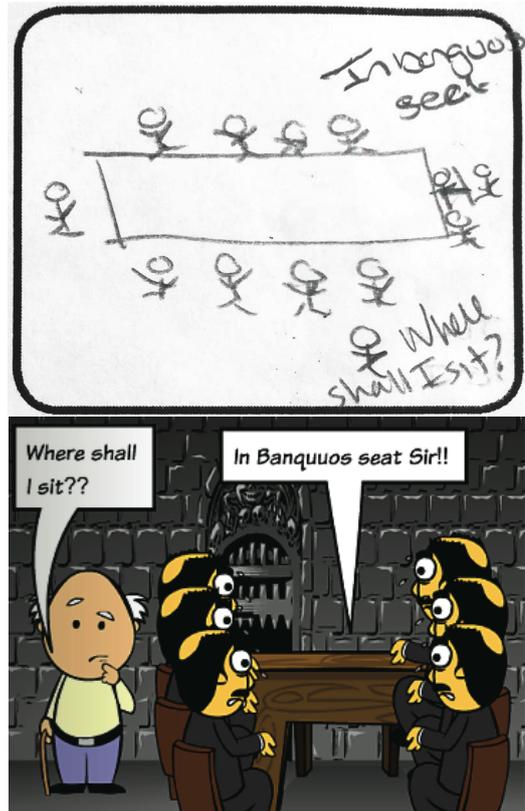

Fig. 1. Macbeth ToonDoo Project: Example panel from planning to implementation

Macbeth: Macbeth was the focus of the third unit of ENG12. The play tells the story of Macbeth, a Scottish soldier that plunges into the depths of darkness to become king regardless of the consequences. The basic premise of Macbeth is that ruthless ambition leads to its own destruction.

To have the students practice their CT abilities, the unit project required the illustration of a scene of the play using ToonDoo [18], an online drag-and-drop comic-creation tool. Before implementation, students had to sketch out a storyboard to describe each of the eight panels of their chosen scene in detail. Figure 2 shows a student-created example of the planning and implementation of one panel in their scene. Although this activity did not provide a computing problem to solve or require students to write a computer program, the goal was for students to use their algorithmic thinking abilities to create a detailed step-by-step storyboard for their scene; this mimics the process of writing pseudocode before implementing it into a programming language. In addition to illustrating a scene, students had to comment on the significance of their scene to the play as a whole; students practiced abstraction by scanning their scene and analyzing the most important passages.

Siddhartha: Siddhartha follows the journey of self-discovery and enlightenment of a man in ancient India. This particular novel was introduced to the high school seniors to provoke deeper understanding about how enlightenment relates to knowledge, how knowledge relates to them and their goals, and how Eastern philosophy correlates to the Western World.

The Siddhartha unit project involved the creation of online blogs. Each student worked individually using Google Blogger as a creative outlet to reflect on ideas, plot structure, and Eastern philosophy within the novel. The targeted CT principle was algorithms through creativity; the goal was to end the semester with a project that the students could personalize and make their own, while practicing their writing skills and their ability to follow an algorithm (set of directions). Students were given documents with all of the necessary information to successfully complete the project and were graded on how well they followed directions. One of the blog topics dealt with the source material the author may have used when writing the novel. Students were given several ancient Buddhist and Hindi texts, and asked to use reasoning with abstraction to find the correlations between the texts and Siddhartha.

C. Additional CT Modules

In addition to increasing students' ability to analyze literature, Staley's course also aimed to help students acquire necessary college-ready skills. Each activity also highlighted CT concepts.

Introduction to Algorithms: The term "algorithm" is not part of the typical high school student's vocabulary. For that reason, it was necessary to introduce the concept through an engaging activity. This module was designed to teach students the definition and step-by-step nature of an algorithm, how algorithms are used in their every day life, and how to make an algorithm better. Real world examples of the algorithms students use in their lives included: brushing their teeth, writing an essay, finding a page in a novel, and other daily routines.

In order to show students that algorithms are better when the sequence of steps that are implemented are clear and easier to understand, they were given a sheet of paper and an algorithm to build a Mighty Mite [19] paper airplane. After 20 minutes of folding, no student successfully created a Mighty Mite because the instructions were intentionally ambiguous. After the frustration, the class completed the algorithm by discussing and rewriting any unclear instructions, allowing the class to successfully build their Mighty Mites.

Internet Source Reliability: It is imperative that graduating high school students understand how to find reliable evidence to support their claim when writing an essay. This module uses the CRAAP test [20] to give students an algorithm to determine whether the information given by a source on the Internet is reliable. The CRAAP test centers around five major criteria that help determine the reliability of an Internet source:

1) Currency: the timeliness of the information
2) Relevance: the importance of the information for your needs
3) Authority: the source or author of the information
4) Accuracy: the truthfulness and correctness of the content
5) Purpose: the reason that the information exists

This activity served two purposes: students learned how to apply an algorithm to evaluate Internet sources and gained a new, and appropriately skeptical, perspective about the information available on the Internet.

Prompt Analysis: Analyzing a prompt and providing a relevant response is a vital skill in college. Many times, essay prompts are very long and contain extraneous information which, if not read carefully, can lead to an unrelated essay response. Hence, the class was introduced to an algorithm to help them break down and better understand the instructions in an essay prompt, effectively abstracting only the necessary information:

1) Read the entire prompt.
2) Break apart the sentences.
3) Highlight all important words or phrases.
4) Replace one highlighted word or phrase with a synonym that makes sense to you.
5) Repeat step 4 until there are no more hightlighted words or phrases.

This algorithm also served as a useful tool to be used on the EOCE that requires students to write an essay; the students practiced prompt analysis on the following sample prompt: "Write a multi-paragraph essay and support with evidence from literature you've read this school year. Identify a symbol and explain how that symbol was developed through the entire piece of literature." Together, the class used the algorithm and converted the prompt into a less intimidating prompt: "Write an essay with 3 – 4 paragraphs and support with quotes, examples, or scenarios from a poem, short story, novel, or song you've read this school year. Identify an object that has a deeper meaning and explain how that symbol was unfolded or expanded to become more important through the entire poem, short story, novel, or song."

Summarization: Another important skill that should be learned before college is the ability to summarize a long piece of literature. Students were provided a simple three-step algorithm to do so:

1) Selection: Highlight or write down important sentences
2) Rejection: Discard the sentences that are not crucial
3) Substitution: Convert the highlighted sentences into your own words without altering the main ideas or introducing your own opinions and biases

Along with the step-by-step process, the class discussed some key points to remember when tasked with summarizing any piece of literature. A summary should be objective, without criticizing the author or original source; contain short, simple and self-dependent sentences without redundant phrases or repetitions; and should not reproduce sentences from the original text.

IV. EVALUATION

To recap, this study has been conducted over the course of three semesters across three DISSECT classes (SP14, FA14, and SP15) and two control classes (CC1 and CC2). In total there were 108 students in Staley's ENG12 courses within the time frame of the experiment; Figure 2 shows the number of students in each section (28, 22, 16, 25, 17, students in the SP14, FA14, SP15, CC1, and CC2 classes, respectively). The ethnicity distribution of each class mimics the cultural diversity

of the school as a whole. Figure 3 presents OHS's student ethnicities and the ethnicity distribution of each section of ENG12. According to OHS [21], the student body is 73% Hispanic, 21% Caucasian, 3% African American, and < 1% Asian, Native American, Pacific Islander, and other. All ENG12 classes were composed of 73 - 85% Hispanic, 19 – 27% Caucasian, 0 – 13% African American, 0 – 7% Asian, and 0 – 5% Native American students.

In order to accurately assess student learning of CT, DISSECT utilized a variety of assessment tools and metrics. The following sections describe the assessment approach and results.

A. CT Assessment

Of course, many of the activities and course units were designed to indirectly teach students CT through modules that were relevant to the ENG12 course. At the end of the semester, a five-question test was distributed to the five sections of ENG12: SP14, FA14, SP15, CC1, CC2. The aim was to determine how effective the modules were at integrating CT into ENG12 by measuring the students' ability to apply CT. Below, we will describe the details of each question and then summarize student performance.

Algorithms through spatial reasoning: The first multiple-choice question was designed not only to test students' spatial reasoning abilities, but also to test whether or not the students could use algorithmic thinking in an abstract way. A 2-dimensional image of six different colored faces of a flattened cube and four 3-dimensional cubes (shown in Figure 4) were included with the question: "Using the image, you need to fold the flat cut out in your mind and choose the correct cube representation of the cut out." A successful algorithmic approach to solve the problem would be to mentally fold the flat cut out into a cube one face at a time. After every fold, the four choices should be analyzed to determine if any should be eliminated from the possible solution. After the step-by-step mental completion of the cube, the correct answer should be chosen.

Abstraction through data analysis: The concept of abstracting useful information from data was introduced in the Song Analysis unit of the course. The data question on the test asked students to analyze and determine the possible distribution of fruit from a pie chart, shown in Figure 5, which graphs fruit percentages. The multiple-choice question read:

Which of the following could be the possible distribution of fruit based on the graph?

1) *3 apples, 2 oranges, 5 bananas*
2) *2 apples, 5 oranges, 3 bananas*
3) *5 apples, 3 oranges, 2 bananas*
4) *3 apples, 5 oranges, 2 bananas*

Upon careful inspection of the legend, the solution is obvious. The red slice represents the 30% (3) apples, the blue slice represents 50% (5) oranges, and the orange slice represents 20% (2) bananas.
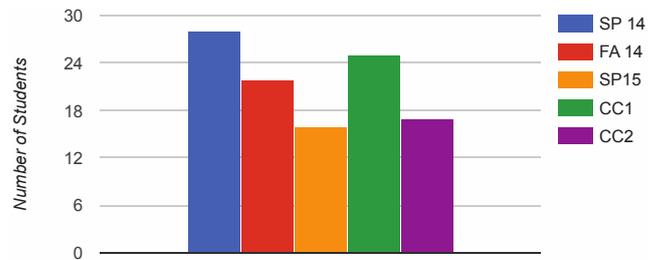

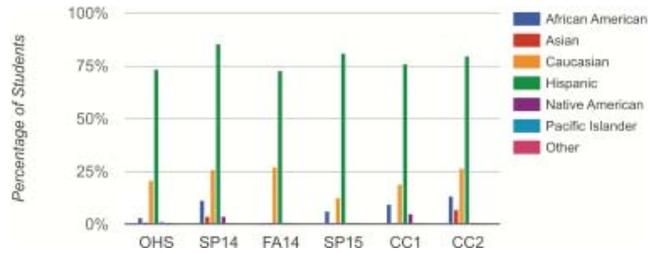Fig. 2. ENG12 Student Distribution
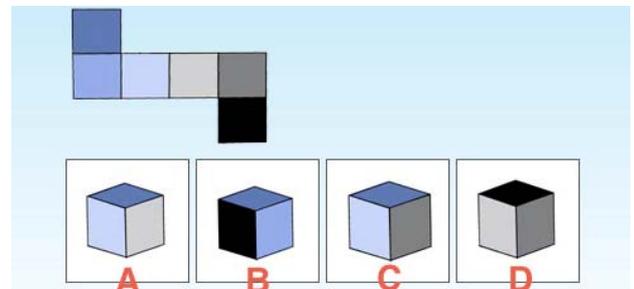

Fig. 3. OHS Ethnicity Distrubution

Fig. 4. CT Assessment Question: Algorithms through spatial reasoning
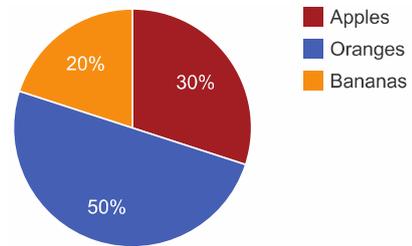

Fig. 5. CT Assessment Question: Abstraction through data analysis

Abstraction through analogy: The analogy question tested the students' ability to use their critical thinking skills to analyze the relationship between two objects. Analogies were not directly taught during the school year, so the question was relatively simple:

Milk is to cow as wool is to _____.

1) *sweater*
2) *sheep*
3) *soft*
4) *farm*

In order to solve this question correctly, abstraction should be used to determine the relationship between the two sets of terms: milk is to cow as wool is to sheep.

Abstraction through prompt summarization: Because prompt summarization was highlighted in the ENG12 curriculum, it was the focus of the fourth multiple-choice question. It instructed students to read a prompt and choose the option that best summarized the directions of the prompt.

Which sentence best summarizes the following prompt?

Works of literature often depict acts of betrayal. Friends and even family may betray their own values. Select a novel or play that includes such acts of betrayal. Then, in a well-written essay, analyze the nature of the betrayal and show how it contributes to the meaning of the work as a whole.

1) *Write an essay that gives an example of a character in a book that may have committed an act of betrayal against a friend or family member.*
2) *Write an essay that explains how an act of betrayal was unfolded to become more important through a piece of literature.*

The correct answer is 2; option 1 fails to require the analysis and development of the betrayal throughout the entire piece of literature.

Algorithms: Throughout the course, students were given many algorithms to accomplish English-related tasks (e.g., writing an essay, summarizing a prompt, analyzing Internet sources, etc.). This question was included to test their mastery at breaking down a problem into a sequence of steps. The question presented a picture of three blocks A, B, and C in an initial position (shown in Figure 6) and the goal was to move the blocks to achieve a specific position:

You have three blocks, A, B, and C that are initially in this position. Your goal is to move the blocks, one by one, in order to have A atop B and B atop C. What would be the correct sequence of steps to accomplish this?

1) *B on C*
2) *C on B, A on C*
3) *C on floor, A on C, B on A*
4) *C on floor, B on A, C on B*
5) *C on floor, B on C, A on B*
6) *C on floor, A on B, C on A*

This problem could be solved in different ways. A brute force trial of each multiple-choice answer will show that among the choices there is only one that will produce the goal position: 5. On the other hand, the problem could be solved logically by analyzing the goal position. It is known that in the end, block C should be on the floor, B on top of C, and A on top of B; these three facts lead directly to the correct solution.

Results: Overall, the students in the DISSECT classes performed better on the CT assessment than their peers in the control classes. Throughout the semester, the DISSECT-enhanced curriculum provided a heavy emphasis on

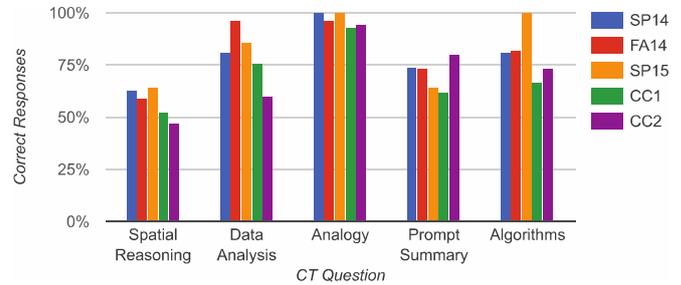Fig. 6. CT Assessment Question: Algorithms

Fig. 7. CT Assessment Performance

algorithmic thinking and reasoning with abstraction. Figure 7 summarizes and compares the performance of each class on each question of the test. Below are the key results and short discussion.

All DISSECT classes, SP14, FA14, and SP15, outperformed both control classes in spatial reasoning, data analysis, analogy, and algorithms. The better performance in spatial reasoning and algorithms was expected because the Introduction to Algorithms activity had a spatial reasoning aspect to it (i.e., folding the paper airplanes) and, in general, many of the modules and activities highlighted or required algorithmic thinking. Furthermore, the Song Analysis project emphasized abstraction through data analysis, so SP14, FA14 and SP15 classes were prepared for this type of question. Regarding the analogy question, the two DISSECT courses did better, but not significantly. This could be attributed to the fact that the question may have been too simple, or that students were already familiar with these types of questions.

The results on the prompt summarization problem were not expected; considering performance, the SP14, FA14, and SP15 classes ranked second, third, and fourth, respectively. Specifically, this question featured an EOCE-like essay prompt. It is hypothesized that the DISSECT classes did not perform better than the control classes, because the control classes were also prepared for the essay-writing portion of the EOCE. Although, the fact that more than 64% of students in each DISSECT class answered the question correctly is a success.

B. EOCE Performance

LCPS requires every graduating senior to take the English Language Arts IV EOCE, which is composed of a reading and writing section. The maximum score for the reading and essay-writing portion of the EOCE is 24 and 20, respectively. Reading exams contain multiple-choice questions that utilize automated grading; the essay-writing portion is anonymously graded by English teachers. While Staley's class aims to improve students' critical reading skills, the CT modules

centered on augmenting students' analysis and writing abilities. Figure 8 shows the performance of the DISSECT and control classes on both sections of the EOCE, as well as the averages for both sets of courses. Regarding the reading section, the graph shows that all classes performed approximately the same on that portion of the exam; all classes received the same amount of critical reading instruction and practice. However, both DISSECT classes outperformed their peers in the control classes on the EOCE writing section; on average, the DISSECT classes scored three points, or 15%, higher than the control classes. EOCE performance data from SP15 was not available before submission.

C. CT Terms Assessment

In an effort to create a standardized form of assessment across all scientific and non-scientific DISSECT courses in the project, pre- and post-assessments are given to each student. The assessment centers around the CT terminology; students are provided with a list of concepts (CT, algorithms, sequence of steps, branching, iteration, variables, clarity, correctness, efficiency, and abstraction), and prompts them to circle, define, and give an example of each concept they are familiar with. By using this standardized document, DISSECT is able to determine how students' understanding of CT is changed throughout the school year across all classes and disciplines.

Each activity on the assessment was graded separately. The circling, or recognition, of terms was graded on a scale from 0 – 10, where each circled term was worth one point. Specifically, the document asked students to define and give an example of up to four terms, so the definition and usage categories were graded on a scale of 0 – 4, where each definition or usage was worth 0, 0.5, or 1 depending on the quality of the response. Figure 9 compares the pre- and post-performance of the ENG12 DISSECT classes on the CT terms assessment. As expected, the ENG12 classes improved in all three areas: recognition, definition, and usage of CT.

D. Post-ENG12 Feedback

A post-survey was also distributed to the ENG12 DISSECT classes to gather student feedback about the course and CT modules. One question asked students to disclose their attitudes about the class units. For each unit, they were asked whether they "hated", "disliked", "liked", or "loved" the unit as a whole including the ENG12 content and related CT modules. Figure 10 charts the percentage of students who responded positively to the course units. In general, students enjoyed the Lord of the Flies, Macbeth, and song analysis units. In all classes, the Siddhartha unit was taught at the conclusion of the semester, and often felt rushed because 12th-graders are released seven school days before non-graduating students; at this point the graduating seniors showed a lower motivation for school and greater excitement for graduation and summer.

The class units, modules, activities, and access to course materials in the DISSECT courses required more technology than the standard English Literature class familiar to most high school seniors. Technologies used during the course included: the Google Drive suite (Documents, Spreadsheets, Presentations), Google Sites, Google Blogger, ToonDoo, and other online resources provided by the OHS Library. The post-survey included a question that asked students how much more
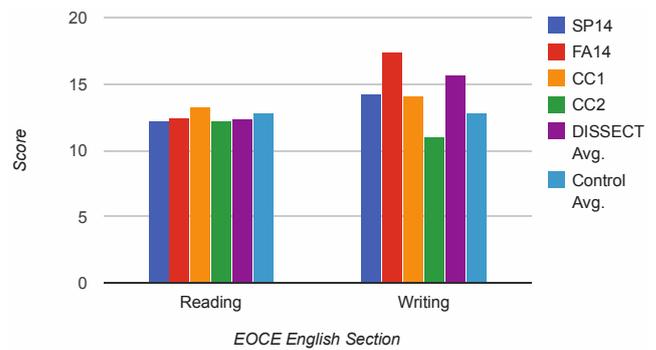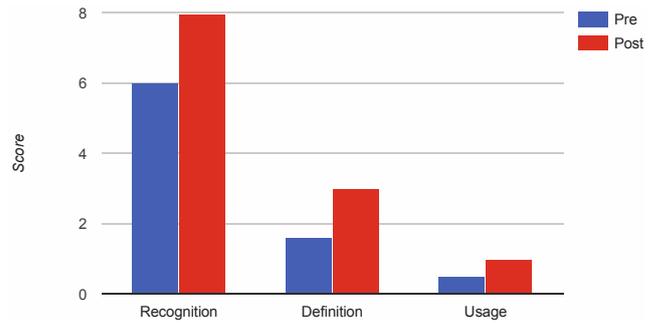

Fig. 8. EOCE Performanc

Fig. 9. ENG12 CT Terms Pre- and Post-DISSECT Performance
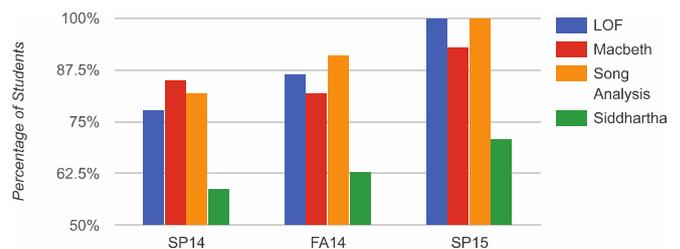

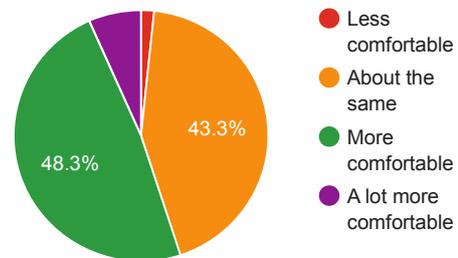
Fig. 10. ENG12 Unit Feedback

Fig. 11. Comfort Level with Technology Post-DISSECT

comfortable they were with technology as a direct result of the class and the projects they completed. Figure 11 depicts the 60 responses of the DISSECT students. Overall, 52% of students felt they were "a lot more comfortable" or "more comfortable" with technology at the conclusion of the course.

Despite the positive results of the incorporation of CT into ENG12, the impact could have been greater if each student had been fully engaged. Students were asked to identify which factors negatively impacted their engagement with the ENG12 course and CT-related modules. We found that students were very willing to admit some of the factors that distracted them.
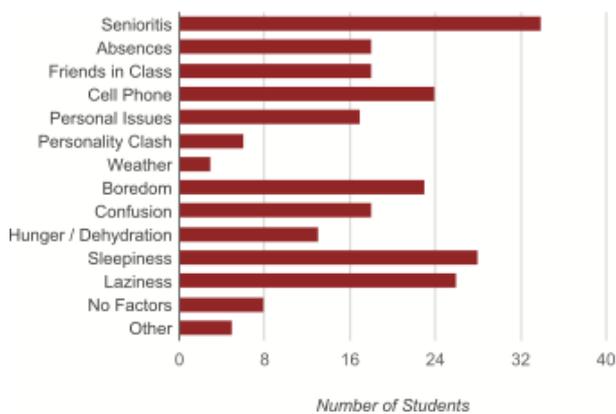
Fig. 12. Factors Impeding Full Participation in CT

Figure 12 shows the number of students across all DISSECT classes who selected a particular distraction. From the chart, it is clear that the factor that contributed to the highest level of disengagement was senioritis, an affliction of high school seniors characterized by a decline in motivation or performance. The next factors that had a significant effect on the DISSECT students were sleepiness, laziness, cell phones, and boredom. Smaller distractions included hunger and dehydration, personality clashes with the instructors, and the weather.

V. CONCLUSION AND FUTURE WORK

In this paper, we provided an overview of DISSECT, a project that aims to provide middle and high school students with essential CT skills. Adopting the perspective that CT is a tool that not only makes the learning of STEM classes more engaging, but also enhances the curricula of non-scientific courses (e.g., English) is unique to DISSECT. The modules presented show that CT can be seamlessly taught within the context of an English Literature course while remaining true to the course description, instruction requirements, and student performance expectations. On average, the students who were introduced to DISSECT modules that featured CT concepts performed 15% higher on the writing portion of the standardized EOCE. This suggests that CT should be explicitly taught as a problem-solving mechanism within the context of all courses, especially courses that are fundamental for success. For example, reading and writing are integral to learning, understanding, and communication in all disciplines, both scientific and non-scientific. Thus, if students can use CT to enhance their reading and writing abilities, they will be better equipped to pursue and succeed in the discipline of their choice.

Furthermore, assessment tools revealed that the integration of CT and English Literature was successful. The DISSECT classes demonstrated their abilities to use algorithms, algorithms through spatial reasoning and abstraction through data analysis; the classes also performed well, but not significantly better than the control classes, on abstraction through analogy and prompt summarization.

DISSECT has discovered an innate relationship between English Literature and CT. As DISSECT modules reach a level of maturity within ENG12 and the student sample size grows, there will be room for further evaluation opportunities. If available, there could be interesting analysis of EOCE data comparing: DISSECT EOCE scores to control scores; DISSECT student performance to school-wide and district-wide performance; and student increase or decrease in performance from ENG11 to DISSECT ENG12.

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