Exploring Computational Thinking across Disciplines through Student-Generated Artifact Analysis

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Context and Research Questions

- Studies indicate a positive effect of computational thinking (CT) on student learning in postsecondary classrooms where faculty in non-CS disciplines infuse CT into courses. [e.g., 1].
- Our study addressed the following research questions:
  - **What types of artifacts do students develop across different disciplines in response to CT-driven problem prompts?**
  - **What types of CT skills do these artifacts exhibit?**

Methods

- Collected 273 artifacts created by undergraduate students across seven course assignments from four disciplines.
- Guided by the CT rubric from a prior study [2], we examined student artifacts for the following skills:
  - **Decomposition**: Students break a problem into its constituent subproblems.
  - **Algorithms**: Students create a series of ordered steps to solve a problem or achieve a goal.
  - **Data**: Students evaluate a data set to ensure that it facilitates discovery of patterns and relationships.
  - **Abstraction**: Students reduce complexity to create a general representation of a process or group of objects so it is both appropriate for the immediate purpose or goal and use in different contexts.

Artifact Descriptions

Assignment	Student Artifact Description	Exhibited CT skills
Math	Students evaluated a dataset of interest using graphs, statistics, and verbal description to answer questions of their own creation. They summarized their work and reflected on their understanding of the CT data skill.	Data
Sociology: Assign. 1	Students designed algorithmic steps to identify the targeted gender of online toy store websites. They also wrote an assignment summary and reflection of their CT algorithmic skills.	Algorithms
Sociology: Assign. 2	Students analyzed datasets to identify sociological topics of interest to them.	Decomposition Data
Sociology: Assign. 3	Students summarized the decomposition process they followed to identify sociological topics of interest.	Decomposition Algorithms
continued on the most right column.		

Example Student Artifacts

Math: Data

Body Image & GPA Data Set

Link to data set: https://www.statcrunch.com/app/index.php?dataid=2612822

Questions

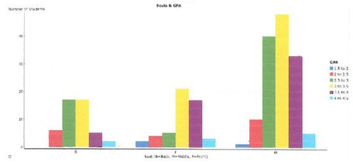
- Does the area you sit in class affect GPA?
- Does body weight affect student confidence and GPA?
- Could student honesty about others cheating affect GPA?
- Could high school GPA affect college GPA?

Statistical Summary

Column	n	Mean	Variance	Std. dev.	Std. err.	Median	Range	Min	Max	Q1	Q3
GPA	236	3.1080763	0.2816 7695	0.530 73246	0.0345 47741	3	2.47	1.9 1	4.38	2.8	3.5

Out of a sample size of 236 students, the average (mean) GPA is 3.1080763. The range of GPA is 2.47, and the standard deviation is 0.53073246. The maximum GPA reached is 4.38, and the minimum GPA is 1.91.

Graphs



Sociology - Assign 1: Algorithms

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-Gather (Toy Image) and (Image Description) for Analysis;
    -Begin (Toy Image) Analysis;
        -Identify 'Action Image': (Hitting, Building, Shooting, etc) and Tally;
        -Identify 'Passive Image': (HandHolding, Waiting, Talking, etc.) and Tally;
            -If Tally 'Action Image' exceeds Tally 'Passive Image', Tally to 'Masc';
            -If Tally 'Passive Image' exceeds Tally 'Action Image', Tally to 'Fem';
    -Begin (Image Description) Analysis;
        -Identify 'Action Words': (Tool, Battle, Arrow, Exploration, etc.) and Tally;
        -Identify 'Passive Words': (Princess, Beauty, Friendship, etc.) and Tally;
            -If Tally 'Action Words' exceeds Tally 'Passive Words', Tally to 'Masc';
            -If Tally 'Passive Words exceeds Tally 'Active Words', Tally to 'Fem';
    -If Tally 'Masc' exceeds Tally 'Fem', Toy is marketed to MALES.
    -If Tally 'Fem' exceeds Tally 'Masc', Toy is marketed to FEMALES.
        -If neither Tally exceeds the Other, tie is broken with Color Spectrum Analysis;
            -Color Spectrum Analysis: Closer to Pink, TIEBREAK FEMALE.
            -Color Spectrum Analysis: Closer to Blue, TIEBREAK MALE.
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Sociology - Assign 2: Data

4. Now find another indicator and produce a layered map with the indicator from step 3. How do the two indicators interact in a geo-spatial setting? How might you explain this, sociologically?

When looking at language, specifically, non-English speakers, I see it is prevelant in the Hispanic Southwest in the same way the Hispanic population is. This can be explained by the idea that these states border Mexico, so there are more hispanics in that region and in turn more people who don't speak english.

what else can we do w/ this indicator?

Sociology - Assign 2: Decomposition

In preparation for your presentation using PolicyMap, let's practice a few things and explore some interests.

1. Identify 2 topics that you can examine in PolicyMap. List them and how they're measured, and what the options are for presenting that data (at what level and measurement).
   a. What other ways can you explore the sociological issue, by way of "editing the layer?"

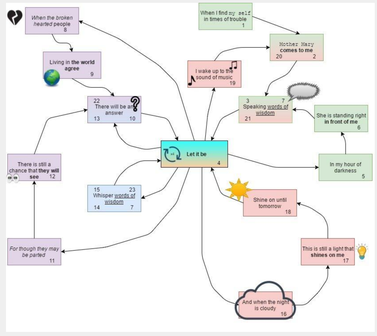
Income → income per household
1. median household income
2. households by income bracket
3. aggregate income
can be measured in dollars, % change; % change (5 years)
Population → school enrollment (2000)
1. public school
2. private school
can be measured in %, number, % change (same), % change (5 years)
you can edit the layer by changing the year of data, the variable, what it is shaded by (the company/organization), color of the map and the ranges of data presented

Music - Assign 2: Algorithms

4. You and your friends decide to compose a piece of music using everyday objects around your dorm or apartment. Create a numbered list that sequences some of the decisions your group would need to make to begin composing your piece. (NB: at this stage, focus on decisions that would get your group started, not larger issues such as total length or formal design.) The small blanks provided are for the numbered steps. They are left blank so that you can reorder steps without having to erase text. NB: the numbers do not need to be perfectly in sequence (e.g. "1 2 3 5 4 6 7..." is fine). Also, you do not need a step for every blank.

1. decide on how many instruments
2. decide the tempo (fast or slow)
3. pick a meter
4. pick a key
5. decide the length of the song
6. pick the underlying beat
7. pick the melody
8. decide what if going to play what part.

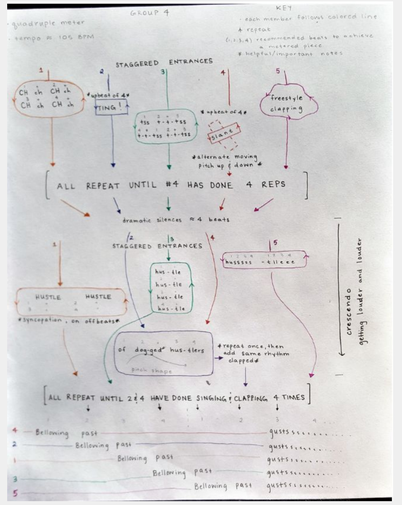
Music - Assign 1: Algorithms Abstraction



Sociology - Assign 3: Decomposition Algorithms

In analyzing our work and data, we recognize and understand the process of decomposition. Each indicator in our layered Policy Map could be broken down into smaller parts which we were able to see through the process of layering itself. When we began our mapping process, we began with observing a general pattern of poverty throughout the United States. We narrowed our selection to poverty in Brooklyn and Queens, focusing on areas we were both more familiar with. We then layered this with foreign born people in those areas as well as alcohol and drug treatment centers, and we were able to pinpoint where all the factors intersected. Unsurprisingly, we found that areas of poverty are often home to people of foreign heritage. Moreover, through adding the data point of alcohol and drug treatment centers, we

Music - Assign 1: Decomposition Algorithms Abstraction



English: Decomposition Algorithms

The pieces that I broke this process into essentially consisted of two phases: the source search and the writing itself. I started with background information about visual novels to give my readers an idea of the topic. After this, I went through a source search followed by a writing up each time a new draft was due, trying to find enough information to expand my research narrative during the writing phase. The final revision then saw the addition of my personal connection to the topic of diversity in visual novels, which I had intentionally withheld from my initial draft since I knew it was going to undergo peer revision, but ultimately did want to add in as it represented a significant factor in the research narrative.

Artifact Descriptions (Cont.)

Assignment	Student Artifact Description	Exhibited CT skills
Music: Assign. 1	Students created websites to document the process they followed in the development of their course projects, showcase course products, and reflected on their CT skills. Those projects included music creation, poem and lyric decomposition, and programming.	Decomposition Algorithms Data Abstraction
Music: Assign. 2	Students responded to a pre-post assessment through a series of four questions, each targeting a specific CT skill.	Decomposition Algorithms
English	Students documented their writing process and reflect on the process of writing a research narrative.	Decomposition Algorithms

Findings

- Students most often used **decomposition** or **algorithm** in these assignments.
- Further, these two skills were often seen together in assignments, regardless of the prompts..
- **Abstraction** was exhibited less than other three skills, indicating the following possibilities:
  - Abstraction is more difficult to exhibit for students
  - Some specific CT skills may be more accessible to different non-CS courses. For example, we saw students use abstraction in the music course more than in any of the other courses.

Contributions and Future Work

- Provided **examples of assignments** from non-CS courses that infused CT.
  - May help faculty identify and implement CT-focused assignments in own disciplines.
- Provided **examples of student work** when students are faced with CT-focused assignments in non-CS courses.
  - Be able to describe student strengths and weaknesses when presented with CT-focused assignments.
- Future work: explore degrees of CT skills exhibited in student artifacts to better understand where students struggle and succeed in using CT skills.

References

[1] Romero, M., Lepage, A. & Lille, B. 2017. Computational thinking development through creative programming in higher education. In *International Journal of Educational Technology in Higher Education*.
[2] Pollock, L., Mouza, C., Guidry, K. R., & Pusecker, K. (2019, February). Infusing Computational Thinking Across Disciplines: Reflections & Lessons Learned. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 435-441).