Knowledge Maps:
A Process Management Approach to Enhance CSS Learning

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Abstract
Novice CSS learners have difficulty understanding advanced CSS techniques and granular details because current CSS learning resources don't provide enough scaffolding to help novice learners. The current iteration of the KM tool allows users to understand granular CSS details and advanced CSS techniques by using a cyclical five-step process that supports users' learning. Based on research about building complex learning representations, this five-step process guides users as they group websites based on common visual features, contrast those websites further to see differences within the similar groups, and finally match the CSS techniques that contribute to the similarities and differences pointed out by users. From our pilot study, we learned that users can successfully go through the five-step process with guidance but further scaffolding is needed to allow users to build a complex knowledge map on their own. In the following sections, we go in-depth about the literature behind this project, the updates and testing we did this quarter, and the next steps we plan to take.

Introduction
Although there are a lot of resources online to learn the basics of CSS, the number of resources targeting intermediate CSS learners is low. In addition, resources specifically helping novice learners understand complex design patterns underlying professional websites are even lower. This means many CSS learners have a solid understanding of the basics of CSS but are unable to understand or create professional websites. The knowledge map project hopes to bridge the gap between intermediate and advanced CSS learners and teach novice learners the professional skills needed to understand the granular details of professional websites. This will be achieved through our new KM web app that guides users as they analyze professional websites.

This web app guides CSS learners through a process of exploring multiple professional websites and the CSS that drives their layout. The tool is intended to help users build a professional-level intuition regarding the building of complex websites. The current KM tool involves a fully integrated KM process management scaffold and comparison website. Previously, the process and comparison were split into a Google sheet and a separate website. However, our new iteration integrates the two into a singular web app. In the app, users analyze professional websites and corresponding CSS while completing a five stepped process to scaffold their analysis (Figure A). The basis for this project is supported by findings of Schwart & Bransford's research which showed that students learn granular details when comparing and contrasting. As such, the KM process allows users to compare and contrast professional websites, providing the scaffolding to discover granular details they might overlook without this deeper analysis.

Literature Review

To better make sense of the problem space, a literature review was conducted to understand what currently exists within the realm of learning sciences and computer science.

Schwartz Paper

Schwartz & Bransford's research shows that students learn best when given contrasting cases to compare [1]. Comparing different cases allows learners to create complex KMs and understand edge cases. Comparing and contrasting requires inquiry about definitions, exceptions, and classifications and thus leads students to pay attention to small details leading to differences and similarities.

Quintana et al. Paper

This academic paper was very helpful in determining the trajectory for the initial knowledge map structure prototype. This paper stresses the importance of having scaffolding for learners and how to incorporate it in effective ways. Quintana et al. breaks down scaffolding into a three-step process: sense-making, process management, and articulation and reflection (Quintana et al). The sense-making phase involves creating hypotheses and interpreting data; the process management phase involves making strategic decisions to control the process; and the articulation and reflection phase involves articulating and evaluating what you have learned (Quintana et al). This three-phase framework ensures that learners are engaged in a scaffolded process that enables them to deeply learn about the content they are learning. This was used as inspiration for the first iteration of the knowledge map structure.

Ambrose Paper

Our hypothesis for this project is based on existing literature that provides several insights into the knowledge map-building process. Susan A. Ambrose's work on the learning process explains that novices and experts differ in how their knowledge maps are structured. Ambrose explains experts tend to have a higher density of connections between different concepts whereas novices might have sparse or disconnected sets of knowledge organization. This work indicates that if novice learners are given a complex cognitive structure to scaffold their learning, they are more likely to increase their knowledge.

Design Space

The user class for this project is intermediate web developers who want to produce professional websites but lack the intuition regarding CSS techniques to do so. Existing solutions have several obstacles that prevent intermediate learners from building the expert intuition required to understand and recreate complex CSS techniques. These obstacles include:

- Lack of in-context learning: Online tutorials teach individuals CSS techniques but don't provide explanations on how these techniques are used within professional websites.
- Time-consuming processes: Users can also build websites until they gain professional expertise. Unfortunately, the process is time-consuming since it would take years to build up the necessary skills.
- Insufficient scaffolding: Code analysis tools like Chrome Developer Tools are often used by CSS learners to understand the CSS behind professional websites. However, the presentation of large chunks of CSS without any supporting structure makes CDT impossible to be used by intermediate learners.

Based on these obstacles there is a design need for a tool that allows users to learn advanced CSS techniques in the context of how they are used for professional websites to allow users to build expert intuition quickly and allow them to gain the understanding necessary to create complex websites. To do this, it's important to ensure the solution provides sufficient support to guide users through analyzing websites. Without enough scaffolding, users will not be able to understand granular details and will struggle to make meaningful comparisons.

We argue that the KM process is able to support intermediate learners to develop expert intuition through the following features:

- **Process Management:** Ambrose's research indicates that learners can build complex learning representations by following a structure that scaffolds their learning. Thus, the entire KM process is wrapped in the five-step process that guides users toward organizing their knowledge into a complex knowledge map connecting the visual features of websites and the CSS that drives them.
- **Comparing and contrasting:** The way in which KM guides users in this process management scaffold is centered on comparing and contrasting visual features of websites. In step 1 of the KM sheets prototype, learners are guided to group websites by common visual features. Then, in step 2, learners find differences within each visual feature group. These two steps guide users' analysis of the professional website in the KM tool by having them compare and then contrast similarities and differences between the websites. However, since this analysis is structured through the KM sheets, users can follow the instructions and frame their thinking through the KM sheets ensuring they note all granular details professionals would identify. This overall emphasis on comparison is based on Schwartz's research, that students learn best when given contrasting cases to compare. Additionally, Step 1's focus on identifying intuitive visual similarities, is based on the sense-making phase of creating a knowledge map discussed by Quintana et. al.
- **Mapping techniques to visual features:** Once they compare and contrast, in step 3 learners are guided to find the techniques contributing to the visual features they identified. This step makes sure not only are users of the KM process able to identify

visual features, but they are also able to identify and understand how they are created with CSS, this step encourages users to reflect on their analysis of the websites.

- **Prominent toggling and tinkering:** The KM tool provides users with a list of relevant CSS techniques that impact website layout. It also includes the functionality to toggle these techniques on and off as well as adjust their values. This allows users to figure out the purpose and impact of these techniques. Since users are learning these techniques in the context of professional websites they are able to understand not just the definition of the techniques but also how they can be applied. Additionally toggling and tinkering allow learners to form their own understanding of each technique and how they can be used in context.
- **Highlighting:** In addition to the toggling and tinkering features, the KM tool allows users to compare pairs of professional examples by displaying the sites and their relevant techniques side by side (figure A). If two websites share the exact same technique with different values, the techniques are highlighted in yellow. If the two websites share the exact same technique and value then they are highlighted in green. This highlighting aims to emphasize patterns of design used by experts by showing users how a technique can be used in different contexts. This functionality is supported by Schwartz's findings since it allows users to compare and contrast the application of a technique across different websites and thus leads users to have a precise understanding of each technique.
- **Cycle Analysis:** as the last step of the KM tool, we've added a reflection step that asks learners to identify patterns of different layout features using the same CSS techniques, and the same layout features using different CSS techniques. This step allows users to think beyond mapping CSS techniques to layout features and gets them to think about different use cases for CSS techniques and different ways of implementing one layout feature.

Additionally, our current iteration addresses issues that surfaced from the previous iterations that prevented users from utilizing the features mentioned above. Pilot testing in Winter 2023 showed that the KM sheet and KM tool were hard to use for users since learners had to learn how to use two tools and learners were given a lot of unnecessary context and complex instructions that overwhelmed users. These issues combined prevented users from identifying granular details, mapping the relevant code to their identify features, and completing the tool use in a reasonable amount of time.

Taking all these factors into consideration, alongside relevant literature and findings from the previous iterations, we have modified the KM sheets and KM tools. All of the changes below were guided by Nielsen's 10 usability heuristics. We decided to use these heuristics are the driving force behind changes we wanted to make since testing from the previous quarter indicated that usability obstacles were preventing us from testing the efficacy of the tool.

1. Visibility of System Status
    a. The tool is responsive to user entry at each step. For instance, as users add differences they note for each site, the website buttons become highlighted green to indicate that a difference for the given website has been identified(Figure C).
    b. We've also allowed users to view a website and its code side by side to allow users to notice the instant effects of the tinkering and toggling of CSS(Figure D).
2. Match Between System and the Real World
    a. We have removed complex wording and unnecessary jargon in the tool to make the instructions for the tool easy to understand.
    b. We also use left and right arrows to help users navigate back and forth between steps (left - go to previous step, right - go to next step) since this is an existing convention for arrows.
3. User control and freedom
    a. The current tool has the ability to allow users to go back to previous steps and undo their entries in case they make a mistake. Additionally, the tool is able to remember users' input in previous steps so when they go back and forth between steps they don't have to refill their answers several times.
4. Consistency and Standards
    a. Since users go through several steps, we've made each step follow a similar layout to ensure users don't face any jarring changes as they switch between steps.
5. Error prevention
    a. To prevent errors like users not entering their findings before going to the next step, we've made the visibility of the step navigation arrows to be conditional on users' progress. Therefore the option to go to the next step is only visible once users have finished entering their data for the current step.
6. Recognition Rather than Recall
    a. Since the tool has a complex process users go through, we've made sure that users are given the necessary information at the right time. This means only showing the necessary instructions only for the current step.
    b. Additionally, in step 2 where users are analyzing websites deeply, their previous entries are displayed once users enter them to help users recall their previous entries when analyzing other websites.
7. Flexibility and Efficiency of Use
    a. Since we're focusing on users that are new to using this tool, we did not spend time altering the tool experience for experienced users.
8. Aesthetics and Minimalist Design
    a. When integrating the KM sheets into the KM tool, we removed all unnecessary details including text, color, and other aesthetic choices that don't contain any information and could be distracting.

    b. When users are going through the exploration and deep-dive steps, users only need to see the websites therefore the CSS and HTML of the websites being viewed are hidden.
9. Help Users Recognize, Diagnose, and Recover from Errors
    a. Although we don't have a lot of error signs for users, we've made the tool intuitive to use so that users don't make errors (see heuristic #5)
10. Help and Documentation
    a. Since users are monitored as they use and tool and guided with instructions in the tool there is sufficient help available to users and therefore additional documentation is not necessary.

Overall, the current process management has the same types of steps: exploration, deep-dive, and mapping to CSS as the last iterations (Figure E). However, during this quarter, we integrated the KM sheets into the KM tool for ease of use. This eliminated a lot of obstacles that slowed down users like going back and forth between tools and a complex spreadsheet interface. Afterward, we made several usability changes like simplifying the complex instructions and breaking complex steps. For instance, the mapping visual features to code step, was split into two smaller, more approachable steps—in step 3 users map visual similarities to CSS, and in step 4 users map visual differences to CSS. Additionally, as users go through each step they are only given the necessary information to complete each step, eliminating other information that could be distracting or confusing to users. Lastly, there is an additional step added after mapping to CSS that allows users to visualize all the complex mapping they made in the previous steps and then reflect upon these mapping through scaffolding questions encouraging them to think deeply about their learning (Figure E).

Testing Results:
The testing we did throughout the quarter gave us insights into usability problems preventing users from focusing on learning CSS. These tests lead to a lot of the changes explained above as well as more specifically leading us to modify instructions, add copy-pasting functionality, and finally lead us to integrate user entry to the KM tool.

We also tested the current version of our prototype on a couple of participants to test for usability and efficacy. These end-of-quarter testing results show that the new prototype had much fewer usability errors based on our observations. Additionally, users were able to identify more meaningful similarities and differences in less time and complete a cycle in less time. For instance, one participant was able to complete 2 cycles of our updated process in less than an hour. Additionally, these tests gave us insight into features we want to implement in the future, which we will discuss below.

Next Steps:
<u>CSS editor usability:</u>
Last quarter, our CSS editor did not surface enough CSS, and as a result users would consistently identify features of the websites driven by CSS which we hadn't included in the tool. So, we spent lots of time identifying and surfacing enough relevant CSS.
However, as a result, it has become difficult for users to intuit what elements of the website they are editing in the CSS editor. There are too many classes and media queries and users might not actually know what part of the website they are toggling, even though they see changes in the viewer.

To fix this, we will edit the class names of the editor to be more intuitive with what the website looks like. For example, we currently surface CSS corresponding to two classes of Italics website: .collections-grid and .cr. These classes correspond to a grid of items to shop from in the center and a sidebar titled "Shop All". If we change the classnames to .central-grid-of-items and .shop-all-sidebar, users would be able to understand what elements of the website CSS techniques correspond to.

<u>Step 5 Visualization and Reflection:</u>
Currently, our step 5 includes a table-like visualization of the complex mapping users make in the previous 4 steps, followed by some reflection questions encouraging users to think deeply about their learning (Figure E). Although this table includes relevant information, it is not structured in a way that scaffolds users to notice interesting or complex connections between CSS and visual features.

In order to improve that table, we will build a tree-like visual representation. Steps 1, 2, and 3/4 would be the root nodes, children nodes, and leaf nodes respectively. Notably, leaf nodes may connect to multiple child nodes as different visual features may be driven by the same technique. Also, a child node may connect to many leaf nodes, as a visual feature can be driven by different techniques. (Figure K)

We also want to improve on the current reflection questions to encourage bi-directional thinking about CSS and visual features, and get users to engage with the different outcomes that could result from one CSS technique. Whereas currently, users map CSS onto visual features, our modified reflection questions will prompt users to map visual effects onto CSS techniques understanding of CSS and visual features bi-directionally. Each technique surfaced in the KM website comparing tool will exist in a column, and each row corresponding to a CSS technique will hold all the different visual features that the tool is able to create depending on arguments given and other techniques it is paired with. For instance, a technique could be grid-template-columns. Then, the visual features it creates are continuously responsive in # of columns (when paired with repeat(autofill())) and also fixed number of columns (when paired with fractional units or percentages).We hope to automate much of this process so that users don’t have to do more unnecessary work.

Large scale user study

After implementing these next step updates, we hope to run a large scale user study. We will recruit novice CSS learners and have those participants go through the KM process. We will also conduct a pre-test and post-test to measure the effectiveness of this iteration. You may notice similarities to our previous EOQ write up here—this is because we did not end up running the user study this quarter, and the goal remains mostly the same.

The current iteration of KM has been tested through small scale, weekly pilot tests, but now we are hoping to conduct a more thorough experiment. We will recruit 20 or more participants to ensure the design gets a wide range of perspectives and allows for appropriate compensation. The selected participants will first be given a pre-test asking them to compare website layouts of two websites and list as many granular visual outcomes and CSS techniques as they can. This test is graded to measure performance before tool use according to a rubric (Figure H). At the start of the experiment, participants will be presented with the KM integrated web-app. Once the process is completed, participants will complete a post-test containing identical questions to the pretest but with a different pair of websites.

Using the same test and grading rubric will allow for tracking differences between pre-test and post-test scores and determine whether the KM process helps users notice granular differences or not.

Expected Findings from user study:

We foresee three main outcomes for this experiment. One is that the new KM fails to facilitate granular understanding. In this case, further research on other KM structures is needed to find a more fitting framework. It is possible that the process management instructions are too pedagogical or still not supportive enough. In this case, the process management needs to be altered based on participants' feedback. The final alternative is that the experiment successfully teaches the participants granular understanding of CSS techniques in both the KM structure and process management.

Works Cited

Quintana, Chris, Brian J. Reiser, Elizabeth A. Davis, Joseph Krajcik, Eric Fretz, Ravit Golan Duncan, Eleni Kyza, Daniel Edelson, and Elliot Soloway. “A Scaffolding Design Framework for Software to Support Science Inquiry.” *The Journal of the Learning Sciences*, 2018, 337–86. https://doi.org/10.4324/9780203764411-4.

D. L. Schwartz and J. D. Bransford, “A Time for Telling,” Cognition and Instruction Vol. 16, No. 4, (1998), 4 (1998), 475–5223. Available: http://www.jstor.org/stable/3233709. [Accessed: 22-Oct-2022].

S. A. Ambrose, “How Does the Way Students Organize Knowledge Affect Their Learning?” in *How learning works: Seven research-based principles for smart teaching*, San Francisco, California: Jossey-Bass A Wiley Imprint, 2010.

Appendix:

Figure A: Step 1 of Integrated KM Tool

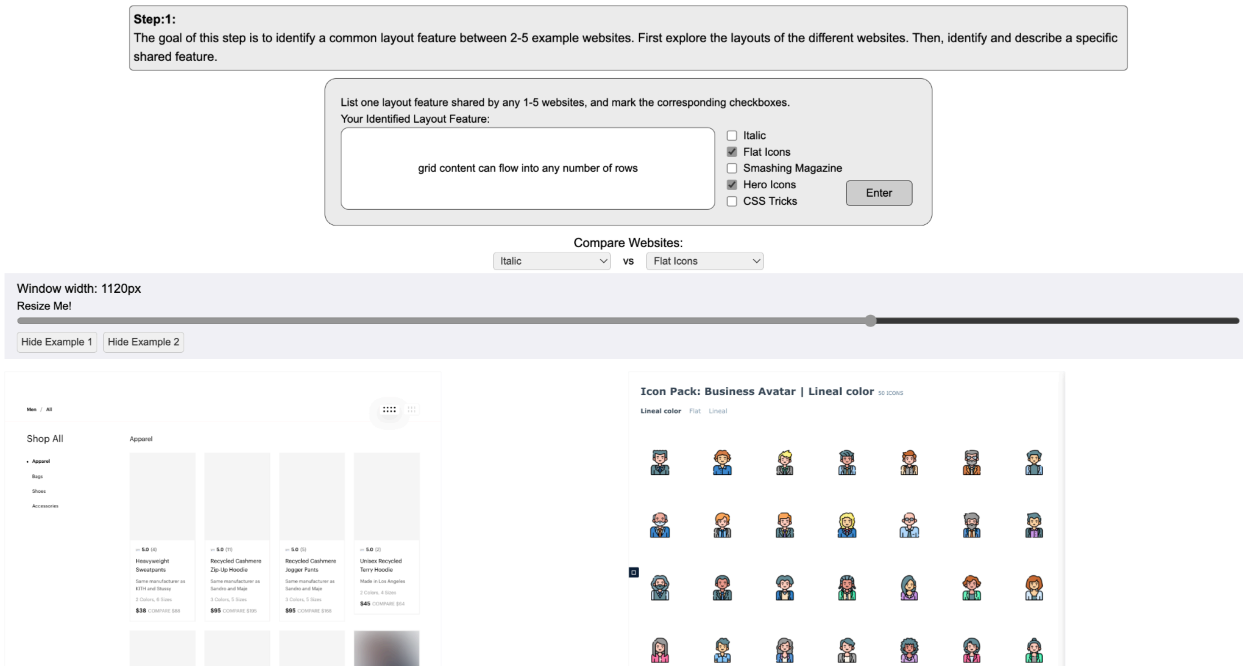

Figure B: Step 2 of Integrated KM Tool

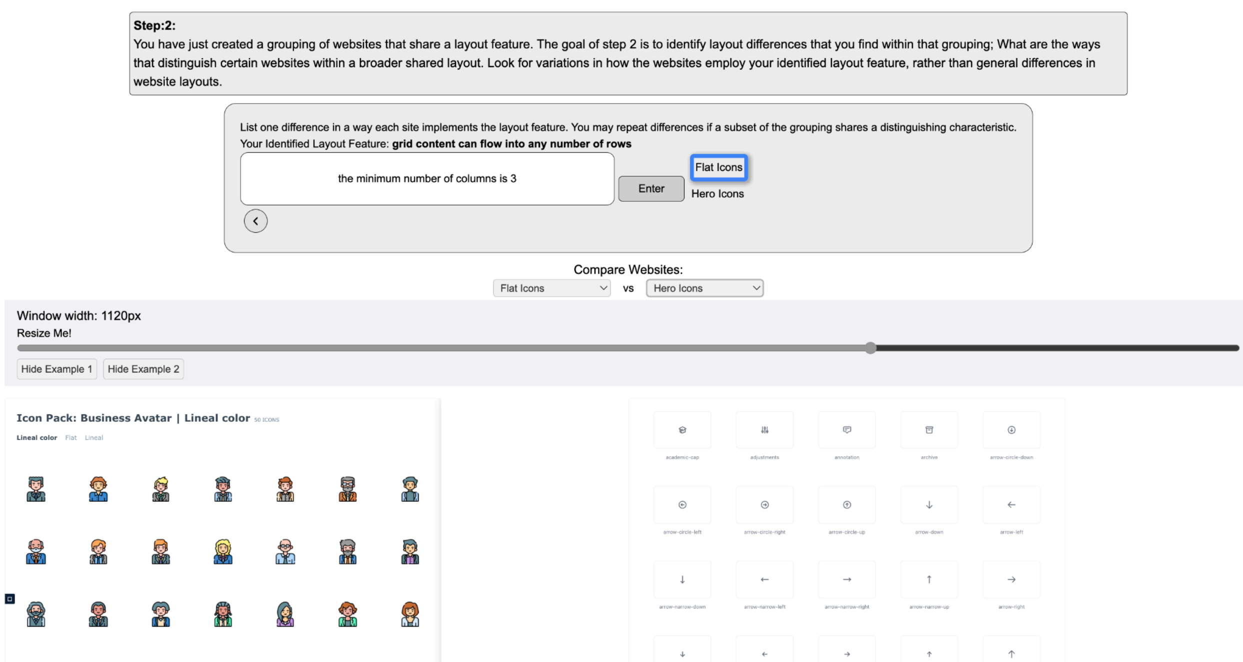

Figure C: Step 3 of Integrated KM Tool

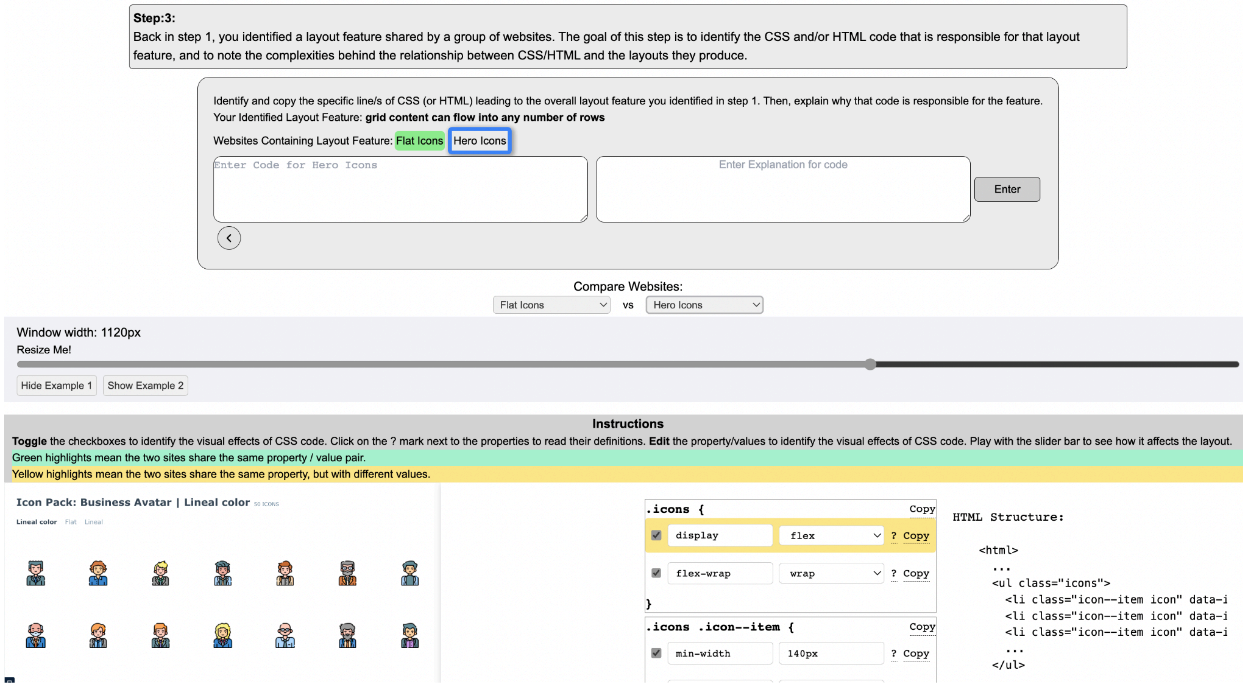

Figure D: Step 4 of Integrated KM Tool

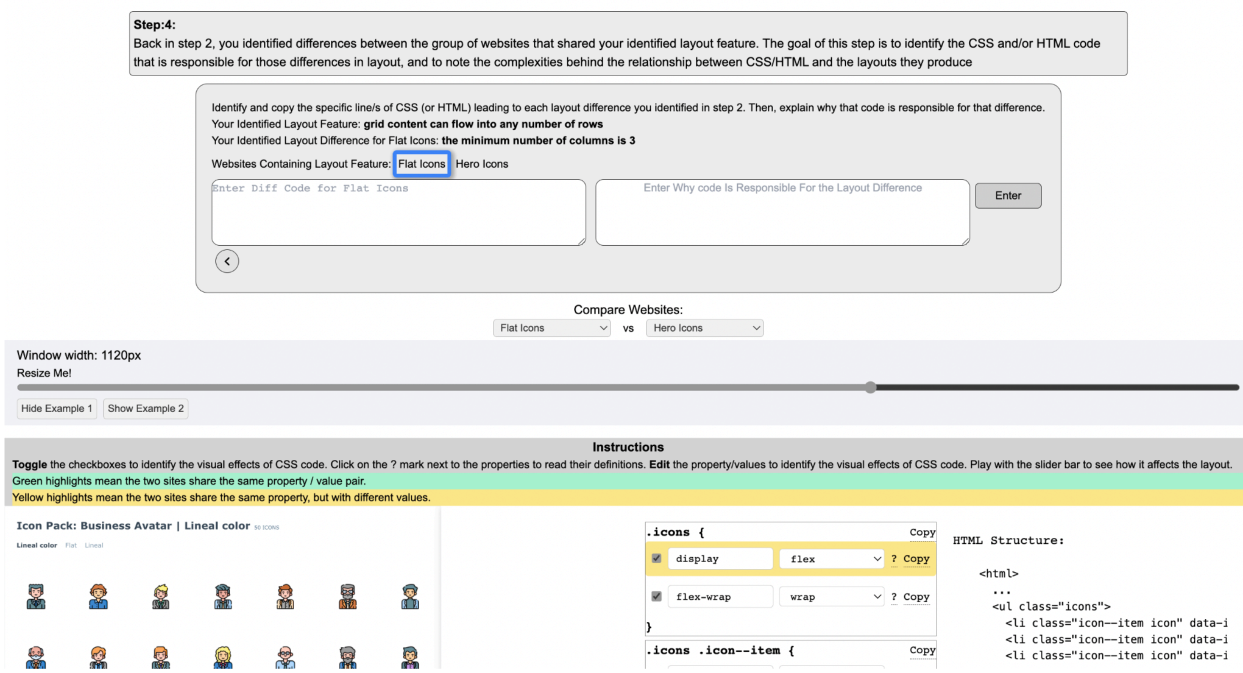

Figure E: Table Visualization of KM process and Reflection Questions (Step 5)

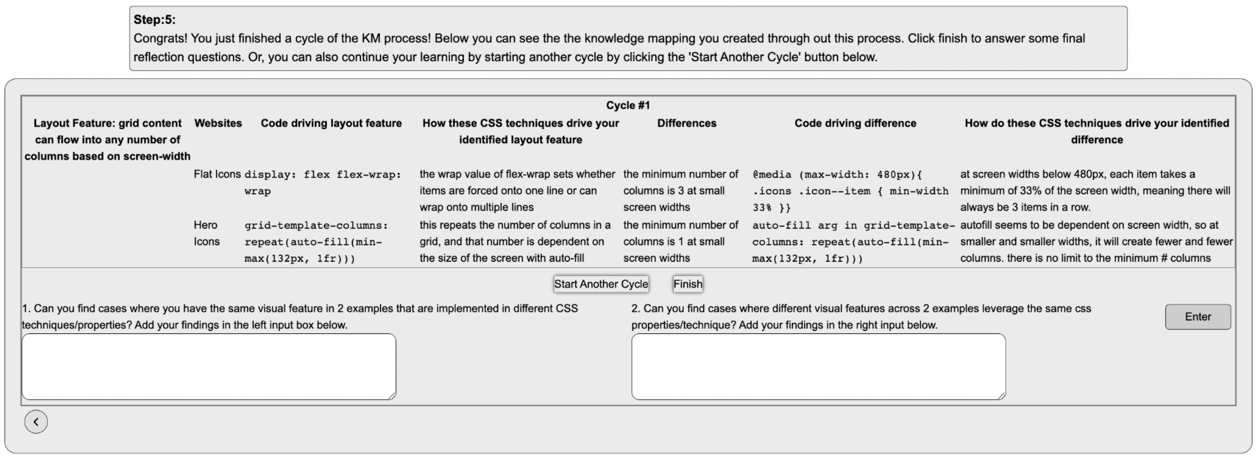

Figure F: Conceptual Approach Diagram: