Iterative Design of a Narrative-Centered Learning Environment for Computationally-Rich Science Learning in Elementary School

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Abstract

Computational thinking (CT) has become an integral 21st Century skill that facilitates problem solving across disciplines (Grover & Pea, 2018). Thus, embedding opportunities and scaffolding for CT learning within K-12 education is now a focus for scholars and practitioners (Hsu et al., 2018). Recent progress in this area has primarily focused on middle and high school levels, where many students now have increasing opportunities to learn CT through designated computer science and STEM courses, while K-5 educators often lack the tools to support student learning of CT skills and practices (Code.org Advocacy Group, 2018). Additionally, an interdisciplinary approach to CT teaching and learning can be more effective than having students learn these skills in isolation from other subject matter (Sandford & Naidu, 2016).

K-5 teachers may be at an advantage for integrating CT across disciplines (e.g., ELA, math, science) and creating robust CT learning experiences, since they teach a variety of subjects
to the same students each day. However, there is a dearth of research that has focused on specific learning technologies and their respective in-platform supports that would help teachers seamlessly integrate CT into disciplinary content learning (Kale et al., 2018; Pila et al., 2019). In response to this need, we are iteratively designing and developing a narrative-centered digital learning environment to engage upper elementary students in computationally-rich science learning. Digital narrative creation offers students an interactive learning experience and enables the creative exploration of scientific phenomena (Henriksen et al., 2016), while also reflecting many CT concepts in the writing and story creation process (Parsazadeh et al., 2020).

**Methods**

To gather feedback from upper elementary teachers about our narrative-centered digital learning environment and its usability for classroom and distance learning settings, we conducted an online focus group in the fall of 2020 which examined teachers’ perspectives on the learning environment’s facilitation of story creation using custom narrative blocks as well as the efficacy of its integration of science, English language arts (ELA), and CT concepts. Our protocol included three components: 1) an introduction to the study and learning environment; 2) teacher experimentation with the learning environment; and 3) a post-experimentation focus group interview. The learning environment used in this study, INFUSECS, is designed to enable upper elementary students to create interactive digital stories and utilizes a custom-built narrative programming environment, where students use a block-based programming interface to create, revise, and visualize interactive narratives.

After a 15-minute introduction and icebreaker activity to help establish rapport within the group, participants were introduced to the overarching goals of the project and learning environment. The teachers were then randomly assigned to Zoom breakout rooms where they had 20 minutes to experiment with the learning environment and then share their perspectives on the learning environment, a narrative planning worksheet designed to facilitate story creation and embedded activities. A researcher observed each breakout room, answered participants’ questions, and addressed any technical issues that arose. At the end of the think-aloud breakout sessions, researchers sought participants’ permission to collect screenshots of the computational artifacts (Figures 1 and 2) produced during the sessions. Participants and researchers then rejoined the main Zoom meeting where participants shared their perspectives regarding the learning environment activities through open-ended interview questions. This portion of the focus group session lasted approximately 25 minutes and the interview questions examined participants’ perspectives regarding the learning environment’s ability to facilitate story creation, its usability, and the efficacy of its content integration.

The researchers held a debriefing session after the focus group to discuss and record field notes. The Zoom sessions, including breakout rooms, were transcribed and divided among the researchers for qualitative thematic analysis. The researchers discussed the qualitative results to reach consensus on the thematic elements of the data. Themes that emerged from the analysis provided impetus for refinements to our digital narrative-centered learning environment. These results are presented in the following sections corresponding to the overarching themes.
Figure 1: Narrative Designer Program Editor

Figure 2: Narrative Designer Animation
Participants

During fall 2020, researchers conducted an online focus group with four 4th grade teachers. The sample consisted of instructors from Northern California, including 3 female and 1 male teacher. The participants were a convenience sample made up of 4 local retired teachers. All instructors had prior ELA and science teaching experience, with 75% of the teachers planning to cover physical science in their classrooms during the school year.

Researchers provided participants with a prior experience survey consisting of 3-point Likert items, ranging from “None” to “A Lot.” Seventy-five percent of the teachers reported having “Some” level of experience using coding activities in their classroom. Twenty-five percent reported having “A Lot” of experience using digital narratives, while the remainder reported having no experience with digital narratives. Researchers collected data via the online Zoom video conference platform using the tool’s main and breakout room functionality.

Findings

Our analysis suggested that teachers believed that the learning environment would facilitate creative digital storytelling with its custom narrative blocks and provide an engaging environment for students to learn science, ELA, and CT. However, teachers experienced some confusion in getting started in the integrated coding environment and difficulties with its accompanying instructional materials, which suggested that additional navigational and instructional supports were needed in the learning environment. Further, the focus group results prompted us to give more consideration to providing a better balance for the integration of the conceptual knowledge we aim to support in physical science with this platform. The following sections provide more detail on the overarching themes that resulted from our analysis.

Facilitating Story Creation with Narrative Blocks

A key aspect of the learning environment is to facilitate students’ abilities to develop science-based digital narratives using custom narrative code blocks. Thematic analysis revealed that the learning environment’s custom narrative blocks aided teachers’ development of their digital stories. Teachers referenced the custom narrative blocks as they encountered them in their exploration of the learning environment and this seemed to spur the creation of their narratives. Teachers were also easily able to discern that story characters could be added using the character-focused custom blocks and without further prompting from the researchers, eagerly began incorporating dialogue blocks for their characters’ interactions.

Teachers seemed to perceive the custom narrative blocks as intuitive and we observed that both groups of teachers spent the majority of their breakout session on the character dialogue of their digital stories. Despite some expressed frustration with typing their characters’ dialog, teachers remained engaged in creating their science-based narratives. However, one point of contention seemed to arise from the appearance of characters not matching teachers’ expectations of how their characters should look. A teacher in one group fixated on a male character offered in the learning environment that was dressed as a nurse despite incorporating the character into their story in another role. The teacher expressed some disappointment with the inability to change the character’s appearance to match their expectation for the role they were assigning, but in this early stage of the learning environment development, the characters...
provided were not customizable. Finally, during the post-interview, teachers expressed that timing would be a key element to using the learning environment and associated activities in the classroom. The learning activities were perceived as enjoyable and useful to their students, but teachers suggested that they would need to spend some instructional time on ELA concepts before jumping into the learning environment for digital story creation. One teacher expressed the need to “lay out [a] lot of groundwork” and another expressed that:

“I think you'd have them work in teams and plan out the story? And they'd have to get some ideas, I think. So, you'd have to brainstorm, like she said and I'd see this being at least [a] week too and using a lot of language arts time before they dive into it. What a story should look like even.”

Usability of the Learning Environment

Data from the usability study indicated that teachers felt the INFUSECS learning environment operated according to specification. Specifically, teachers like the platform and reported that it was engaging and easy to use. While teachers needed some assistance with operating the technology or completing the narrative planning worksheet, teachers found that, overall, there were no issues with the fundamental platform operations, including coding block accessibility or the dragging of blocks and attachment of blocks.

Teachers were able to intuitively and cooperatively use the narrative blocks and planning document framework. The participants worked together to fill out the planning document and use the learning environment. The planning document ‘dialog’ and ‘ask the audience a question’ organization scaffolded the teachers’ thinking during the story design process from a beginning stage, through to the middle and end. The platform code categories and naming of the custom narrative blocks helped teachers to identify the story creation components needed to develop their planned story:

“All right. Stage direction left, right, middle, Hailey exits, Hailey enters. Oh, Hailey enters stage left. Oh, I got it. I got it. I got it. Hailey enters stage left. Dialog, Hailey’s going to say ‘Oh my geezy, is everyone okay?’”

Dragging the blocks onto the main work area was also seamless and the teachers easily attached the blocks together to create their narrative programs. Half of the teachers reached the point of running their narrative programs and seeing the corresponding narrative visualization, and when directed to, successfully observed the translation of their story into visual form.

Teachers did, however, have some difficulties. Participants did not grasp the interactive theatre nature of the platform and thus were not sure how to properly structure a ‘theatre audience’ question and response block. Participants also could not successfully edit the blocks in the question space of the planning document. The participants tried multiple times to click the question box and enter text, but the image formatting did not allow text entry. Within the learning environment, two teachers had initial confusion about what to do when they first opened the software. As a result, they sought researcher direction and support. In another portion of the session, half of the teachers had some difficulty navigating the integrated coding environment because they did not understand how to close/exit the code category sections of the workspace. One teacher expected the coding environment to be platform agnostic and unsuccessfully tried to access it using an iPad. Despite these challenges, with a small amount of feedback from the
researcher and additional time, the teachers were able to move through each initial source of difficulty without further assistance.

Content Integration Efficacy

Our focus group findings indicated that the participants were able to make more explicit disciplinary connections to ELA in comparison to science and CT. Several teachers indicated that they would specifically dedicate ELA instructional time for the activities, in particular, allowing students a few days to draft and build their stories. One teacher felt the learning environment would be well-suited as a tool for generating the creative writing genre of playwriting and dialogue between characters while others remarked at how the built-in scenery of the narrative environment such as the waterfall could be sources of energy on the island. However, in the post interview they expressed some concern that students would need group brainstorming sessions to make these explicit science connections.

Finally, our investigation probed the participants to discern if they noticed potential opportunities for CT integration. Although teachers in our study never explicitly named CT concepts as a part of the learning experience, their practices exhibited CT elements that could potentially be integrated into their pedagogy with the platform through professional development and training. Moreover, the teachers suggested that graphic organizers could help students decompose and abstract the necessary story elements and scientific components that would be needed to compose their narratives. During the interview, teachers shared ideas to consider for the learning environment that aligned with CT. For example, one teacher noted, “I think you’d have them work in teams and plan out the story,” indicating he saw the environment fostered opportunities for collaboration. Another teacher discussed the learning environment’s value for creating artifacts:

“At the end when we saw what we created, that's why I feel like my kids would really like it. Because I see what the end could look like and if they can see what the end would look like, I think they would go crazy wild because it's great.”

Our observations of teachers’ interactions with the environment also indicated that our participants saw the animation tool and the programming blocks as means for fostering CT concepts and practices like debugging, tinkering, and evaluation as we witnessed them engaged in these processes.

Iterative Development and Future Work

To address concerns raised during the focus group, we implemented an initial set of iterative refinements to the INFUSECS learning environment. The first refinement aimed to improve usability of the software. Upon logging in, users now encounter an overview map (Figure 3) highlighting key navigational features and an introductory video sequence (Figure 4) to help each participant connect the individual pieces of the environment with the overall goals and directives of the platform.
Figure 3: INFUSECS Overview Map

Figure 4: INFUSECS Introductory Video
The second refinement was the incorporation of the Science Content Explorer. This component teaches foundational energy concepts (Figure 5), engages users with an interactive simulation of energy conversion methodologies (Figure 6) and provides proximal learning opportunities through sense-making questions.

The interactive simulation feature also aims to bridge the gap between the learning environment’s science learning objectives and the expression of energy conversion principles within students’ digital narratives. Finally, a set of story starter blocks were added as a scaffold, enabling users to play a simple story animation and familiarize themselves with the instantiation and design of digital narratives.

Building on these refinements to the learning environment, future work will include conducting classroom feasibility studies. This will include both remote and in classroom studies as in-person learning becomes safe for students, teachers, and researchers. Feedback gathered from these studies will drive further refinement of the learning environment.

Figure 5: Science Content Explorer Foundational Energy Concepts
Figure 6: Science Content Explorer Interactive Simulator
References


