Promoting Multidisciplinary Digital Learning: A Design-Based Approach to Creating Teacher and Student Support Materials

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Digital learning environments are used frequently in K-12 classrooms. Such use can require skillful orchestration as teachers need to understand the affordances of the learning environment, sequence of activities, and when and how to intervene with students. Using a digital learning environment in a multidisciplinary classroom context makes the design of support materials for teachers and students even more essential. To design for effective teacher orchestration in the classroom, we created a comprehensive set of materials for our multidisciplinary digital learning environment. We employ the design-based intervention research framework to trace the contextual and practical iterations these materials underwent. Additionally, we provide next steps for our work and considerations for the broader community.

Introduction

The use of digital learning environments in classrooms to supplement or reinforce traditional curricula can require adept teacher orchestration. Teachers should have a solid understanding of the affordances of the learning environment, the ordering of activities, and when and how to intervene with students. This may occur with ease in single-subject classrooms where the teacher has specialized pedagogical practices for the discipline. However, in a multidisciplinary context, teachers may need additional pedagogical support such as physical resources (i.e., documents) and substantial professional development (PD) that provides not only content background but emphasizes the use of the digital learning environment and strategies to support teacher confidence for presenting and troubleshooting (Zimmer & Matthews, 2022).

We used a design-based approach to create teacher and student materials for our multidisciplinary digital learning environment to support computational thinking, science, and language arts learning. This approach is predicated on an iterative, open-ended design process that uses stakeholder input and outcomes from stakeholder use of materials (Brown, 1992). The classroom technology and computer science education research communities have utilized this approach for curriculum design (Hansen et al., 2016), teaching (Koehler & Mishra, 2005), and technology-based activity development (Comber et al., 2019). Below, we illustrate our process for designing support materials for teachers using our InfuseCS digital learning environment.

Framework

Design-based research (DBR; Brown, 1992) methodologies are powerful approaches for studying, understanding, and theorizing about real-world learning. When using DBR, research modifications occur systematically; changes that are made allow for testing, evaluation, and theory-building (Brown, 1992). Design-based intervention research (DBIR; Fishman et al., 2013) emphasizes the mutual and necessary relationship between research and practice and underscores the role of iterative refinement. We acknowledge the importance of practitioner needs and input as the driver behind refinement.

Method

InfuseCS—designed for upper elementary students (age 9 to 11)—utilizes a problem-based learning scenario to drive student interest. In the storyline, scientists with a well-stocked ship have found themselves marooned on a deserted island and they must use their salvaged materials to power their village. Pedagogically, InfuseCS has three complementary and overlapping components: (1) a Science Explorer where students engage with multimedia content and simulation activities to learn about energy transformation (Figure 1a), (2) a Narrative Designer that uses a block-based programming language for students to create an interactive science narrative (Figure 1b), and (3) Makerspace-type activities that reinforce science content and bolster student narratives (Figure 1c). Our team has designed a set of support materials for each of these components.

Figure 1

The three InfuseCS complementary and overlapping components: (a) Science Explorer; (b) Narrative Designer; (c) Makerspace activities.

Focus groups, pilot studies, teacher PD, and classroom implementations with students (n=106) and teachers (n=8) were conducted across two states in the United States. The research team—comprising experts in computer science, computer science education, education, and science as well as current and former K-12 teachers—made initial design decisions for the support materials based on literature, findings from related projects, and in-class teaching experiences. The support materials we present underwent a series of refinements, informed by teacher and student stakeholders and our observations of the materials in use.

Support material design and redesign

Using a DBIR approach to developing InfuseCS materials has meant the integration of different disciplines (science, making, narrative writing, computational thinking, and coding) and perspectives (student, teacher, and developer). InfuseCS materials have undergone a series of iterations based on feedback, observations, and continued research. The testing and iteration process for materials for the three main components of the learning environment (Science Explorer, Narrative Designer, and Makerspace) are explained in the next sections.

Science Explorer

The Science Explorer (Figure 1a) introduces students to science concepts (energy types and conversion) related to the overarching learning scenario. Building on initial feedback from both teachers and students, we implemented several improvements to the Science Explorer materials. In particular, in PD sessions, teachers expressed some concern over their own perceived science content competence and their efficacy in being able to support student learning. The team then created content “cheat sheets” that included infographics, Frayer models, and factoids, exposing students and teachers to relevant terminology and helping correct misconceptions.

Narrative Designer

The Narrative Designer (Figure 1b) assists students with creating their interactive science narratives using a block-based programming interface. A narrative planning worksheet, designed as an external tool to guide students’ narrative construction after they completed the science investigation portion of the intervention, was intended to support the transition from planned narratives, or narrative notes, to block-based narrative programs using story blocks (e.g., character, locations on the island, and dialogue). Initial observations during school visits, along with feedback from students and teachers, led to several iterations of the narrative planning worksheet. However, teacher input and researcher observation indicated the students lacked interest in using the worksheet in the narrative planning process. This information supports removing the worksheet and encapsulating the narrative planning into the learning environment itself.

Makerspace Activities

Maker activities (Figure 1c) were developed and piloted in two categories: storyline cutout kits and energy source and receiver conversion kits. These are outlined below.

Energy Conversion Kits

Energy conversion kits that align with the virtual components seen by students in the simulation portion of the science investigation included both energy sources, or inputs (battery packs, solar panels, windmills, and hand cranks), and energy receivers, or outputs (fans, sirens, lights), along with wires to make connections. Although these kits are considered external elements, they directly align with the circuit-building activities in the simulation activity, and they align conceptually with the different forms of content delivery (text-based and audiovisual). The first energy conversion kit maker activity developed was titled: Reinforcing Physical Science Concepts through Play. A teacher guide and a paper-based student worksheet document were produced for this activity. A separate document was also created to assist teachers in setting up an energy conversion station in the classroom. The student worksheet included gamified checklists to guide the students through the building of simple and complex circuits using the components in the kits. Due to time constraints typical of classrooms, we opted to use a structured approach, rather than unstructured exploration.

The original energy conversion kits utilized a full set of energy sources, receivers, and wires, allowing the students to assemble various types of circuits similar to the ones that the scientists on the island would use. After iterative testing, the flow of the program was divided such that the students would have a set amount of maker time using the conversion kits and exploring the science content, followed by an equal amount of time to draft their written narratives and convert them into block-based narrative programs.

Storyline Cutouts

The storyline cutout maker activities utilized characters and prop assets built into InfuseCS, such as generators and solar panels. The purpose of this activity is for students to construct a story set and prepare to tell their story to peers via a physical manifestation of their story, similar to a puppet show. As part of the storytelling, the students also have access to the physical science materials from the energy conversion kits (e.g., battery pack, motor, fan). In the piloted version of this activity, as a student’s animated story plays on the screen within the InfuseCS software, the student would simultaneously act out the story using the physical characters, props, and materials.

Although some students enjoyed the process of setting up the characters and props to act out their stories, there was concern that the cutout kits may not provide enough added value towards achieving the overall learning goals to justify the time required for their inclusion. Research team meetings, teacher feedback, and observations of students interacting with the hands-on materials also placed the circuit building with the energy conversion kits (rather than the storyline cutout kits) right at the center of the intersection of the science content, problem-solving, and narrative expectations of the program. In line with the findings from the analysis and testing of the narrative planning worksheets, it appears that minimizing assets external to the digital learning environment may be beneficial.

Conclusion

Teachers have extensive knowledge of their students, their interests, and the practicality of an activity (Gomez et al., 2018). Likewise, students are experts in their own knowledge and comfort with using novel materials in classrooms. As such, involving stakeholders in the iterative design process is essential. By way of focus group and teacher PD feedback, as well as observations during classroom implementations, the research team made several significant changes to the materials that teachers and students use in InfuseCS. To support teachers, we created science content cheat sheets. Narrative Designer changes centered around developing a paper worksheet to support students' ability to write from a character's perspective; this will soon be tested as a system-embedded component. Changes within the Makerspace component emphasize students' use of hands-on energy conversion kits that mirror the needs within the problem scenario. These DBIR-inspired changes are slated for classroom testing.

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