User-Centered Research and Design
of a K-5 Digital Literacy Curriculum

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Abstract. A research team engaged in a user-centered research and development approach to the creation of "Professor Garfield's 21st Century Literacy Curriculum," a comprehensive, web-based tool for K-5 teachers. This process consisted of a four-phase approach that included thorough exploration of the state-of-the-art in digital literacy tools, a survey of K-5 teachers designed to understand their technology use and perceptions of digital literacy, design thinking and empathy research with more than 30 K-5 teachers, and summative user experience testing with teachers from across the country. This approach illuminated key requirements for an interactive system that supports digital literacy instruction, as well as the primary factors that motivate teachers to adopt new online teaching tools.

Keywords: Digital literacy · User-centered design · E-learning

1 Introduction

Although K-5 students have more access to technology than ever before, few resources exist that provide teachers with a clear definition of digital literacy, help them understand how to integrate digital literacy instruction in their classrooms, and allow them to easily and effectively build digital literacy lesson plans for their students. As such, digital literacy pedagogy is still relatively undefined and inconsistently executed. This is largely due to barriers teachers face in integrating technology in the classroom, including their personal comfort and skill with technology [3], access to professional development associated with technology use [1], and skepticism about the effectiveness of technology in the classroom [7]. Although 90% of American teachers recognize the importance of digital literacy instruction, more than half feel underprepared to implement it in the classroom [12].

A number of online teaching and learning tools exist that offer standards-based online curriculum [11] or digital literacy lesson plans, activities, games, and videos [5]. However, these tools often fail to provide a comprehensive approach to instruction that recognizes the complex path to digital literacy. Instead, they often focus on one or two components of digital literacy, such as using the Internet or e-safety or finding credible information online. Others fail to address digital literacy at all, assuming instead that the mere act of using the Internet is enough to effectively engage today's "digital natives." Moreover, most existing web- or app-based tools fail to provide teachers with

support for effectively implementing them in the K-5 curriculum [8]. As a result, students and teachers alike are left dramatically underserved.

This paper describes, discusses, and illustrates a user-centered research and development approach to "Professor Garfield's 21st Century Literacy Curriculum," a web-based tool created at Ball State University in collaboration with the Professor Garfield Foundation. This novel curriculum is presented as a comprehensive, web-based tool that provides K-5 teachers with (1) content to advance their conceptual understanding of digital literacy; (2) customizable, standards-based, grade-appropriate digital literacy exercises for young learners; (3) lesson plans and supplemental instructional materials; (4) a learning management system that allows teachers to track students' progress toward digital literacy; and (5) a dashboard on which teachers can create and design their own digital literacy lessons.

2　Background

In the late 1990s, Garfield creator Jim Davis began to think about how Garfield's history as a proponent of early childhood literacy might translate in the digital world. Davis soon came upon the idea of the Professor Garfield learning portal and the Professor Garfield Foundation (PGF), a non-profit educational collaboration between Paws, Inc. (the global headquarters for Garfield the Cat) and Ball State University in Muncie, Indiana. Launched in 2004, this collaboration led to the development of professorgarfield.com, a nationally recognized leader in innovative digital learning content with a primary emphasis on children's literacy and creative expression.

However, the national dialog about literacy education has evolved to include the successful use of digital tools for meaning making in online and digital environments. Thus, PGF has begun to explore how the Professor Garfield website might effectively reach beyond traditional notions of literacy by fostering literacy skills central to a learner's success in the digital age.

It is also important to note that although today's students have grown up with technology, digital literacy is not innate. Those skills must be taught incrementally over time through age- and grade-level appropriate methods, just like other subjects. In this context, being digitally literate is the ability to make and share meaning in different modes and formats; to create, collaborate, and communicate effectively in digital environments; and to understand how and when digital technologies can best support these processes [6].

However, research shows that although most teachers understand that technology integration is important to student success, more than half do not feel prepared to use technology in their classrooms. According to Samsung VP Ted Brodheim, "With the increasing popularity of Chromebooks, tablets, interactive whiteboards and apps in classrooms today, it's evident that technology is a critical tool for today's learners. However, our new research highlights that teachers are not yet receiving full support to harness the power of technology and truly transform classroom learning into a 21st century experience" [12].

Thus, the Center for Emerging Media Design & Development at Ball State University partnered with PGF to develop a novel set of online learning tools to support

K-5 teachers and students in their digital literacy efforts. "Professor Garfield's Digital Literacy Curriculum" is grounded in a framework [6] that emphasizes eight key components of digital literacy: functional meaning making, creativity, critical thinking, cultural and social understanding, collaboration, finding and selecting information, effective communication, and e-safety. Moreover, a user-centered approach to the project design identified key requirements to ensure that the Professor Garfield site meets the functional and practical needs of K-5 teachers.

3   Project Design

The development of "Professor Garfield's 21st Century Literacy Curriculum" was based on a four-phase process that included (1) a thorough exploration of the state-of-the-art in digital literacy instructional tools and extant literature related to digital literacy education, (2) a survey of K-5 teachers designed to understand their perceptions of digital literacy and technology use in the classroom, (3) design thinking and empathy research with teachers in two states, and (4) summative user experience testing with teachers from across the country. This user-centered approach allowed us to better understand key requirements for an interactive system that supports digital literacy instruction, as well as the primary factors that motivate teachers to use new web- or app-based teaching and learning tools.

3.1   State-of-the-Art and Extant Literature

In an effort to more fully define digital literacy as a pedagogy and skillset, a number of models for educational technology were explored. Review of these materials was expansive and provided both direction and inspiration for our digital literacy curriculum. The most prominent of these are highlighted in the results section of this paper.

3.2   Digital Literacy Perceptions and Practices Survey

A survey validation study was first conducted in two phases to ensure items were accurate and dependable. First, three digital literacy experts were asked to review the survey and provide feedback via the Questionnaire Appraisal System (QAS-99) [13] to evaluate the wording and accuracy of questions. The expert reviewers were selected because they had similar expertise in digital literacy. To maintain independence of the reviews, all reviewers were asked to conduct the reviews individually. Based on the feedback from each expert, revisions were made to address concerns.

Following the expert review, five elementary teachers from a local laboratory school were recruited to participate in a 30-min validation focus group. This second activity helped ensure questions made sense consistently to members of the target audience. In this session, teachers were asked to review and discuss each question and provide feedback about the nature and content of each question. Based on this feedback, revisions were made and a final *Digital Literacy Perceptions and Practices* survey was developed.

To better understand the specific nature of teachers' perceptions and practices related to digital literacy instruction, a fully-validated survey was distributed to 1,000 K-5 teachers in Indiana and Michigan. For this survey, the Departments of Education for Indiana and Michigan provided email addresses for K-5 teachers in those states.

3.3   Design Thinking and Empathy Research

To form a more comprehensive understanding of teachers' classroom practices and inform the development of digital literacy exercises, the research team engaged in 15 collaborative brainstorming sessions with more than 50 K-5 in-service and pre-service teachers over a six-month period. Teachers were first interviewed about how they integrate technology in their classes. They were also asked what factors contribute to adoption of teaching and learning apps and/or websites. Likewise, teachers engaged in participatory prototyping as a method for brainstorming interactive exercises that foster digital literacy and reinforce language arts concepts, such as phonemic awareness, reading readiness, and storytelling.

Throughout the design and development process, the research team also engaged in iterative usability and user experience research with more than 30 K-5 teachers. Teachers from two schools in Chicago and in Muncie, Indiana were shown exercise prototypes and concepts at both low- and medium-fidelity, and provided valuable feedback about the nature of each exercise, as well as the interaction design of the site.

3.4   Summative User Experience Testing

During the 2017 and 2018 International Society for Technology in Education (ISTE) Conference, attendees were introduced to the Professor Garfield's 21st Century Literacy Project and then asked to sign up to become beta testers for future usability and user experience studies. A total of 100 teachers from 34 states agreed to participate. Participants were divided into five groups, one for each of the five active digital literacy modules that comprise the current iteration of the site. A separate set of questions focused specifically on each exercise module was administered to 20 teachers each.

Participants were contacted via email and asked to complete a remote user experience protocol that engaged them in a systematic walk-through of the Professor Garfield digital literacy offerings using a website testing tool. The task-based survey was also provided as a PDF attachment for teachers who preferred to complete a paper version and return it via postal service or email. The survey included seven key demographic questions and nine tasks that required participants to walk through the site's main sections and provide feedback about the explanatory content, educational merit, and ease of use related to each section and the custom content management functions of the site. Tasks focused on the homepage, digital literacy instructional videos, teacher registration process, course creation, exercise summaries, assignment creation, lesson plans, digital literacy exercises, and grading system. Demographic questions, as well as most task questions, were the same for all participants. However, each of the five groups was given a unique set of questions related to one of the five digital literacy exercises outlined above. The survey was live from June through August 2018.

4   Findings

The following sections provide an overview of what we learned at each stage of the user-centered process.

4.1   State-of-the-Art and Extant Literature

A few notable online solutions for digital literacy education exist. learning.com provides interactive modules designed to "equip students with critical skills including keyboarding, word processing, digital citizenship, and online safety, as well as media and information literacy skills." The site also advertises "a project-based approach to teaching digital literacy and integrating technology into core subject instruction." Likewise, EDSITEment and ArtsEdge provide lesson plans, activities, and online games. Similarly, a number of sites offer resources to help teachers in the classroom, including The News Literacy Project, DigitalLiteracy.gov, Common Sense Media, and Web 20.14. Although they offer an abundance of information and content, they do not address the complexities of teaching and learning digital literacy in K-5.

Additionally, TPACK (Technological Pedagogical and Content Knowledge) [9] emphasizes three types of knowledge instructors need to combine for successful edtech integration. Likewise, the Substitution Augmentation Modification Redefinition (SAMR) Model [10] provides insight about how computer technology might affect teaching and learning. However, neither provides a comprehensive and definitive framework for understanding the broad range of skills a learner must acquire to become digitally literate.

Ultimately, the review of literature revealed that digital literacy is about mastering ideas, not keystrokes. Many scholars and educators have evolved the concept, and according to Hauge and Payton [6], to be digitally literate empowers students to use digital tools – such as online learning environments, software, hardware, etc. – for critical thinking and problem solving. Hauge and Payton's framework identifies eight core components of digital literacy: e-safety, finding and selecting information online, functional technology skills, critical thinking about technology use, creativity in digital environments, the role of technology in their lives, effective communication, and collaboration in digital environments (Table 1). This work underpins the digital literacy curriculum eventually built for this study and informed the development and validation of the perceptions and practices survey outlined in the next section, as it provides a clear operational framework for identifying and defining digital literacy skills. Furthermore, [6] advocates for a cross-curricular, age-appropriate approach to administering essential digital literacy instruction. They note that digital literacy is not a subject, but rather a skillset that students develop.

Table 1. This project is based on eight components of digital literacy [6].

Digital literacy component	Definition
Functional meaning making	Ability to operate software and/or hardware
Finding & selecting information	Ability to find accurate, reliable information online
Effective communication	Ability to communicate online
Collaboration	Ability to work with others using technology and/or effectively collaborate online
Critical thinking	Ability to think critically about technology use
Creativity	Ability to connect ideas and generate creative digital products
E-Safety	Ability to use good judgment, engage in safe in tech use
Effective communication	Ability to appropriately communicate with digital tools
Cultural awareness	Ability to understand how technology shapes the world we live in

4.2   Digital Literacy Perceptions and Practices Survey

A total of 297 teachers started the survey, however, only 249 responded to all survey items. Individuals who didn't complete the survey were removed from the dataset, resulting in a 24.9% response rate. Demographic data, including teaching and/or administrative responsibilities, was collected. Then, participants were asked to respond to 17 questions – including both Likert-scale and open-ended questions – about technology use and digital literacy perceptions and practices. The survey was estimated to take about 20 min to complete.

Respondents were asked a number of general questions about how they approach technology and digital literacy instruction in their classrooms. Most respondents (78%) reported that their schools offer the flexibility and resources needed to teach about technology. Likewise, more than half of respondents (65%) reported that their schools offer the flexibility and resources needed to teach about digital literacy. However, as Fig. 1 illustrates, when asked approximately how many hours per week they dedicate to teaching students how to effectively use digital tools, more than half of respondents reported one hour or less.

Fig. 1. Teachers' classroom practices related to teaching digital literacy

Respondents were asked whether class time is structured so that students regularly have the opportunity to engage in specific activities related to the eight components of digital literacy: e-safety, finding and selecting information online, functional technology skills, critical thinking about technology use, creativity in digital environments, the
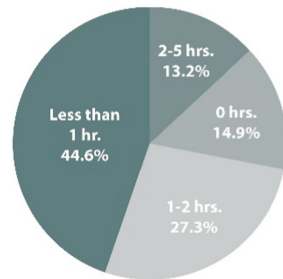
role of technology in their lives, effective communication and collaboration in digital environments. Figure 2 illustrates how educators responded to these questions.
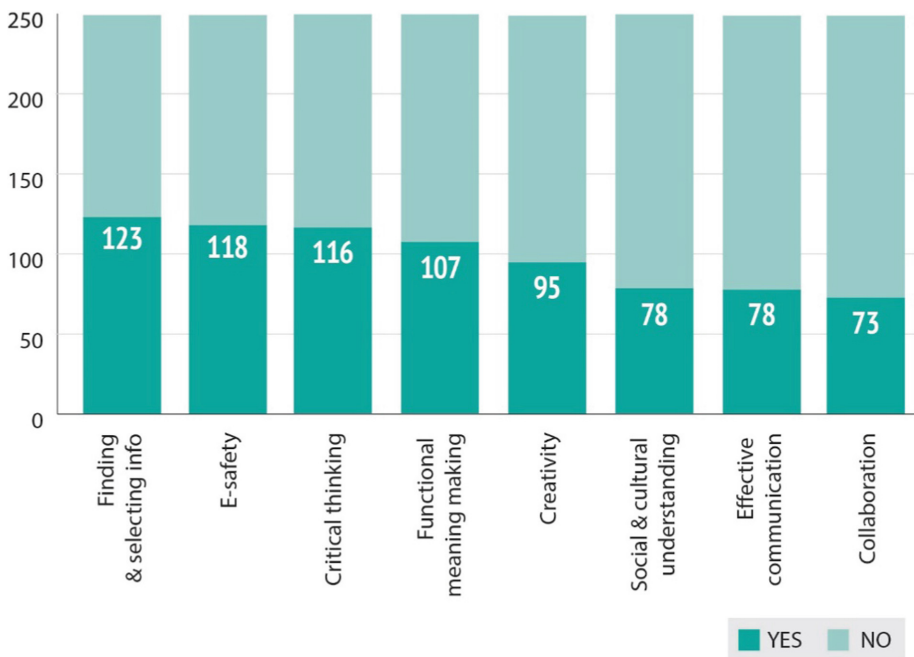

Fig. 2. Teachers' responses to questions about whether class time is structured so that students regularly have the opportunity to engage in specific activities related to the eight components of digital literacy.

Findings also suggested that: (1) professional development opportunities are limited for learning how to teach students how to use digital tools; (2) teachers' understanding of digital literacy is relatively shallow; (3) teachers often focus on tools and software as opposed to underlying principles that govern digital literacy.

4.3   Design Thinking and Empathy Research

Not surprising, the need for a simple design was a key theme during early-stage concept tests. Participants emphasized that both K-5 students *and* teachers require a clean, minimalistic design and clear interaction patterns for the site to be learnable, memorable, and easy to understand. Additionally, teachers indicated that digital literacy exercises must deliver a comprehensive lesson, fun enough to hold a young learner's attention, and brief enough mitigate the chance that they would lose interest.

After several rounds of design thinking, semi-structured interviews, and participatory brainstorming and prototyping, seven key requirements emerged: (1) teachers must have a clear understanding of digital literacy; (2) instructional materials must be

grounded in a framework of digital literacy; (3) the site must provide teachers with support materials, such as video tutorials and lesson plans, and offer clear direction for how to implement them in the classroom; (4) teachers must see a clear connection between what students are learning and established curricular standards; (5) exercises must be age and grade appropriate; (6) exercises must be fun and motivating to K-5 students; and (7) teachers must be able to track students' progress toward digital literacy.

Based on these requirements, the final website (professor.garfield.com) includes the following key features (Fig. 3):
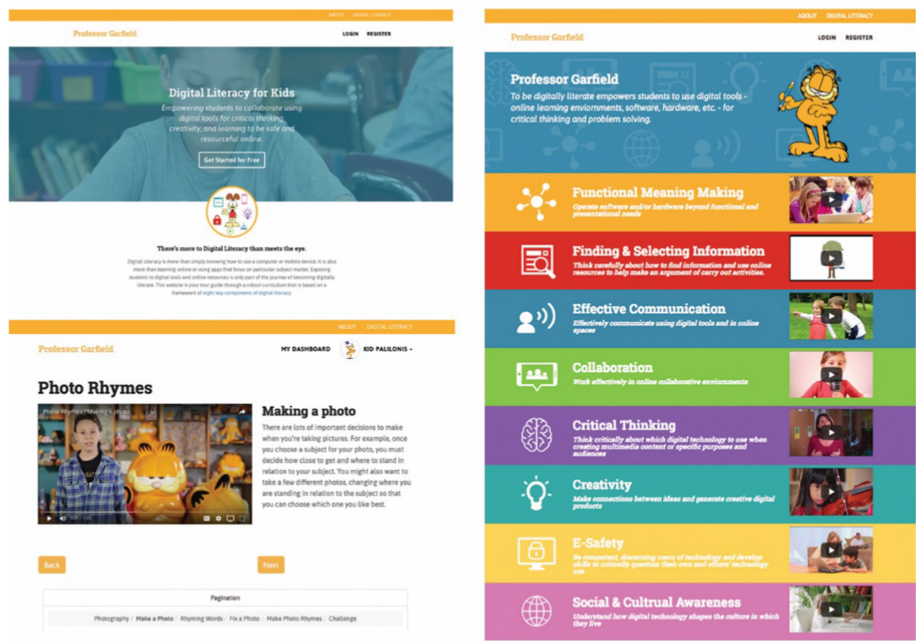
Fig. 3. A home page (top left) provides an overview of digital literacy and the site's main offerings. A digital literacy page (right) includes brief instructional videos that define eight components of digital literacy. Videos provide teachers with a clear understanding of each component and exemplify the skills necessary for a student to master digital literacy. Videos are accompanied by an introductory lesson plan that teachers can use at the start of a semester or unit called "Eight Days of Digital Literacy with Professor Garfield." Digital literacy exercises (bottom left) guide students through short tutorial videos prior to engaging in an activity designed to teach one or more of the eight components of digital literacy.

Brief instructional videos define each of the eight key components of digital literacy. These videos provide teachers with definitions of each component and exemplify the skills necessary for a student to master digital literacy. An introductory lesson plan called "Eight Days of Digital Literacy with Professor Garfield" is also included. This comprehensive plan provides teachers with simple activities they can do

with students to build a foundation for digital literacy. For example, in one activity, students explore how technology has changed the world. Among the topics discussed are the advent of online schools, online shopping and 24-h access to television, movies, music, and news. Students are introduced to Google Earth to illustrate the global community facilitated by the Internet. Finally, they are asked to search for their school and tour the community surrounding it while the teacher shows some of Google Earth's features.

Fig. 4. A teacher dashboard (left) allows teachers to explore exercise descriptions and lesson plans, as well as assign exercises to their class. Cross-curricular lesson plans include downloadable handouts and PowerPoint presentations. Lesson plans also indicate for which grade level each exercise is best suited and the Common Core Language Arts standards and International Society for Technology Educators each lesson covers.

Cross-curricular lesson plans for five exercises include downloadable handouts teachers can print and use, as well as customizable PowerPoint presentations. Lesson plans indicate for which grade level each exercise is best suited (Fig. 4). Lesson plans also indicate which Common Core Language Arts standards [2] as well as which International Society for Technology Educators (ISTE) standards [4] each lesson covers.

Five exercises are each designed to achieve three main goals: (1) teach one or more of the eight components of digital literacy, (2) reinforce concepts related to language arts (e.g., phonemic awareness, reading instruction, storytelling), and (3) leverage the popularity of Garfield in fun, engaging ways.

For example, in an exercise targeted toward first and second graders called "Photo Rhymes," students learn how to tell stories using photos, how to make and edit photos using digital cameras, how to upload photos to a web-based system, and the importance of saving your work in digital environments. Then, they are given a list of words and asked to find objects that rhyme, take photos of those objects, and upload them to the website. Teachers are able to customize the list of words and are encouraged to use spelling or vocabulary words from a language arts lesson. Additionally, students can unlock digital literacy badges and downloadable prizes as they work toward becoming digital literacy masters.

A learning management system allows teachers to track students' progress through the digital literacy curriculum, assign grades and badges for each exercise, and provide comments/feedback on students' digital literacy submissions. Additionally, a dashboard allows teachers to review, select, and customize digital literacy exercises and lesson plans.

4.4   Summative User Experience Testing

Thirty-six teachers participated in the final user experience test (36% response rate). Five sub-groups responded to unique questions about one of five digital literacy exercises: Photo Rhymes (n = 9; 45%), Culture Video (n = 7; 35%), Narrate Garfield (n = 8; 40%), Video Editing (n = 5; 25%), Digital Footprint (n = 7; 35%).

Responses to questions about general system features – including homepage, digital literacy page, teacher registration, course creation, exercise summaries, assignment creation, and grading – were overwhelmingly positive. In nearly all cases, 80% or more of participants responded positively (*strongly agree* or *agree*) to questions about the quality of all areas of the site. Responses to questions about ease of use and perceived appropriateness for K-5 students were equally positive. Open ended responses illuminated several positive attributes and room for improvement:

- Homepage is attractive, and/or informative (n = 22).
- Videos are high-quality, clear, appropriate, informative, easy to understand (n = 17).
- Site is all-in-one resource for digital literacy (n = 24).
- Teachers learned more about digital literacy (n = 12).
- Exercises are fun (n = 17), engaging (n = 4), easy to understand (n = 12), and informative (n = 10).
- Homepage needs more information (n = 16).
- Digital literacy videos might be difficult for younger students to understand (n = 8).
- Younger students may struggle to complete exercises because the videos contain too much talking and not enough explanatory visuals (n = 7).
- Educational standards on the lesson plans should not be state-specific (n = 11).
- Grade levels specified in lesson plans may not be correct (n = 4).

- In several places, videos and/or instructions were difficult to understand/follow (n = 6).

These results have been used to make improvements to the site, including a redesign of the homepage, additional video production, a revised approach to reporting educational standards for each exercise, and simplified instructions for younger children.

5   Discussion

Establishing a user-centered approach that engaged K-5 educators in the design and development process was critical for a number of reasons. First, it allowed the design team to create a positive dialogue throughout the research process with an eye toward developing a curriculum informed by the teachers who might use it. Given the considerable barriers that teachers face when it comes to integrating technology in the classroom, this approach ensured that curriculum and site design decisions will mitigate those barriers. Anecdotal, but certainly important, the feedback we received from teachers throughout this process was extremely positive. Teachers were generally enthusiastic about the content, excited to have comprehensive digital literacy tools for their own development and that of their students, and grateful that we spent a great deal of time with teachers in many different schools and school systems to determine what strategies and tools would work best for them and their students. Many times, teachers expressed to use that all too often, technologists, entrepreneurs, and innovators develop teaching and learning tools based on assumptions they have about how teachers teach and how young people learn. This approach, they said, often leaves teachers feeling undervalued and results in products, services, and methods that are not realistically implementable in the average K-5 classroom.

Additionally, this user-centered approach appropriately respected K-5 teachers' pedagogical content knowledge by giving them a voice in the curriculum development process. By engaging teachers throughout the design process, the team was able to transform their innovative ideas into new digital literacy activities. Furthermore, it allowed us to design a robust digital literacy curriculum that is comprehensive and appropriate for the K-5 audience, as well as motivating for teachers to use and implement in the classroom. Finally, feedback during iterative design, development, and testing phases allowed us to effectively and incrementally build a website that will be useful, relevant, and easy to use. Summative user experience testing uncovered specific ways in which the final product both met and fell short of desired outcomes. Feedback from that research has been used to improve and polish the site. Ultimately, this project has demonstrated the true value of a user-centered approach to web design and development, particularly when there are significant barriers to adoption and highly-specialized domain knowledge among the audience and key stakeholders.

5.1   Conclusion and Future Work

Feedback from user-centered activities informed site improvements, and we are currently developing three more exercises focused on identifying facts vs. opinions and storytelling online. The site will officially launch for free use in Spring 2019. We are currently running a pilot study of the full site with six K-2 teachers and their students (approximately 140 children) at a campus laboratory school to further investigate the efficacy of the site, lessons, and exercises in a live classroom setting. We are also planning a large-scale implementation study in local Muncie schools for Fall and Spring 2019. Finally, we are currently developing a dashboard for creating personalized digital literacy and language arts lesson plans.

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