Chapter 3
Open Source Online Learning in Rural Communities

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ABSTRACT

Anyone is free to use open source software without the need to purchase the right to install it. Despite its appeal to school and technology leaders in rural communities, they are less likely to install it than others. In this chapter, three cases in which open source technology was installed to support teaching and learning in three rural communities are described. In each, the systems were deployed and refined using decision-making grounded in educational design research. The projects are detailed, and the method of technology planning is assessed. Unanswered questions are also addressed.

INTRODUCTION

Educational communities face many challenges as they seek to prepare students for the technology-rich future in which they will live and work. Educators must create curriculum that reflects rapidly changing content expectations (Dede, 2010; Susskind & Susskind, 2015) and that reflects emerging and incompletely understood economic, political, and cultural norms (Miller, 2011; Wokurka, Banschbach, Houlder, & Jolly, 2017). In addition, school leaders must support teachers as they create classrooms that reflect new discoveries from the learning sciences (Benassi, Overson, & Hakala, 2014; Sawyer, 2008). All of these changes can be traced, at least in part, to rapidly evolving information and computer technology and its effects on the creation and dissemination of information (Benkler, 2006). For rural communities, these challenges are exacerbated by several factors (Beeson, 2001). Rural schools tend to be smaller, thus they lack the economy of scale that can provide greater resources for larger populations (Tholkes & Sederberg, 1990). Because they are more widely dispersed, travel time between rural schools can limit the responsiveness of professionals who are shared among multiple sites. Because they serve small populations, rural educators frequently teach outside their area of specialty (Miller, 2012).

Advocates suggest the technology used to deliver online learning can be adapted to address many problems faced by educators and school leaders. For example, school leaders can use online learning to

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expand opportunities for students (Dabrowski & Lodge, 2017), facilitate teachers' professional learning (Baran & Correia, 2014), and support authentic learning and assessment (Herrington, Reeves, & Oliver, 2006). Platforms for online learning are available from both proprietary publishers and from open source communities; open source platforms can be obtained and installed at no cost to the user. Ostensibly, open source tools will have wide appeal to school and technology leaders in rural communities because of the minimal costs. Despite this, there is evidence rural schools are less likely than suburban and urban schools to use open source tools to manage information and to promote learning (Kimmons, 2015). In this chapter, the author describes three projects in which open source distance learning technologies were applied to the professional needs of educators working in rural communities in the northeast United States; the planning and decision-making that focused the projects were grounded in educational design research (McKenny & Reeves, 2012).

Open Source Technology

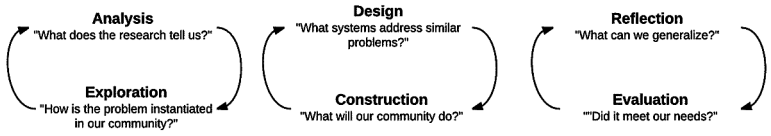
A growing community produces open source software and open educational resources (OER) communities have grown and their products have begun to compete with and complement commercial products. They are also increasingly used in both K-12 and higher education. Baker (2017) suggested open resources are defined by dimensions of transparency and freedom, and these characteristics can be traced through the information products created by educators for many generations. Transparency is that characteristic of open resources that allows users to access and modify the original works; freedom is that characteristic that allows use of the products without the need to purchase or license the work. More importantly, however, freedom entails the rights to create and distribute derivative works.

The software used in these projects is published and licensed under the GNU General Public License (Free Software Foundation, 2016); the Apache License, Version 2.0 (Apache Software Foundation, 2017); or the Creative Commons Attribution-ShareAlike 3.0 Unported License (Creative Commons, n.d.). All of these licenses fit Baker's (2017) dimensions of transparency and freedom. In the cases described in this chapter, school and technology leaders obtained copies of open software, installed it per the conditions of the license, and customized it using the options available in the software. In no case did the author or any other individuals involved with the projects vary the source code of the software or create derived works.

Educational Design Research

This chapter describes both the software used to support virtual teaching and learning as well as the planning decisions and processes that led to changes in the ways the technology was configured and used. In these cases, the school and technology leaders followed a multi-step process grounded in educational design research (McKenny & Reeves, 2012) Educational design research is a variety of user-based research (Stokes, 1987) in which researcher-practitioners seek to simultaneously understand phenomena and to design interventions that meet human needs. McKenny and Reeves (2014) described educational design research as "the iterative development of solutions… to practical and complex educational problems" which leads to "new knowledge that can inform the work of others" (p. 133). The iterative processes are undertaken for three distinct phases (see Figure 1), and each phase finds researcher-practitioners consuming (or creating) literature for the wider community and also reconciling the literature with the local circumstances.

Figure 1. Phases of educational design research
Adapted from McKenny & Reeves (2012).



Analysis/ exploration comprises both literature review and deconstructing local situation to clarify the problem and identify relevant factors that are unique to local the instantiation; this work leads to deeper understanding of the problem. The product that emerges from this phase is a description of the problem and the nature of the anticipated solution. Design/ construction includes the development of interventions; existing technology and practices become the basis for the initial designs and further iterations improve them according to the local circumstances. Evaluation/ reflection finds researcher-practitioners both determining the degree to which the intervention met local needs and articulating new knowledge that can be applied to other problems and that can be used by other researcher-practitioners.

PURPOSES

Qualitative data are provided for two purposes. The first is to illustrate the iterative analysis/ exploration and design/ construction phases of educational design research (McKenny & Reeves, 2012) and to describe how the process influenced planning decisions and outcomes. The second is to articulate several generalizations about the practice of using open source online learning platforms in rural schools that appear to be supported by this data.

METHODS

As part of the author's duties as either an internal or external consultant, he facilitated projects to use open source online learning technologies in six schools between 2013 and 2015; planning and decision making followed the generic model of educational design research (McKenny & Reeves, 2012). During analysis/ exploration, the author engaged school leaders in a two-part semi-structured interview (Drever, 2006) held in a single session; the interview was focused by the prompts, "tell me about the situation you seek to improve" and "tell me what you want students and teachers to experience." The author summarized these into a problem statement and a statement of anticipated outcomes; these were revised with the leader or leaders until they were satisfied it accurately summarized the situation. These statements gave direction to the groups convened to begin design/ construction of interventions to solve the problem.

Once the leader deemed the problem was sufficiently understood and the expected outcomes accurately defined; other professionals (including licensed and non-licensed teachers and educational technology professionals) engaged with the author to develop an initial intervention. From the beginning, it was made clear to those involved with design/ construction that the work would be iterative so the interventions would be redesigned and reconstructed based on observations made and feedback gathered during the process. Participants understood also they would keep journals that would be used as data to research the projects.

The primary role of the author in the design/ construction phase was investigating open source solutions that appeared to solve the identified problem and that were compatible with extant information technology systems. In some cases, the author installed and configured the initial open source solution, then provided training while it was first deployed. The author also provided technical advice and support for expanding the open source solutions and refining configurations as the iterative phases of design/ construction proceeded.

In 2016, the author contacted the schools in which these interventions had been deployed. In three cases, the leaders who initiated the projects were still employed and the project was still active. In those three cases, transcripts and summaries of the original exploration/ analysis interviews with leaders, agendas and minutes from planning meetings, and journals kept by participants during the design/ construction phase were reviewed to describe the work. These descriptions were composed by reviewing minutes that recorded meetings to identify decisions that were made, then analyzing participants' research journals and other documents to describe the situations that led to the decisions. Finally, the leaders reviewed the descriptions and marked any sections they identified as potentially inaccurate; those were rewritten after the leader and the author reviewed and agreed on the meaning of the original documents.

The leaders who initiated the three cases described in this chapter were also interviewed in 2016. These two-part interviews were conducted via video conference; each was scheduled for thirty minutes and the two sessions separated by about one week. The first session was focused on the degree to which the project had solved the original problem and the second focused on generalizations about the process and project. In addition, a school leader who initiated a fourth project, which had been abandoned, was interviewed. Transcripts of these interviews were analyzed using the constant comparative method (Glaser, 1965); the author and another researcher who was enrolled in a graduate level education research course at the time coded the transcripts. The themes that were common to both reviewers are elucidated in the findings.

THE PROJECTS

The three projects described in this chapter were undertaken by school leaders and professionals working in public schools located in rural areas of New England. The schools are all members of larger organizations that provide a similar range of clerical and administrative support, including technology support, to member schools. In this chapter these organizations will be called "alliances," and schools in the same organization will be "allied" schools. One case occurred in a single school with no alliance to other schools in the study; one case included several allied schools, and the third case comprises data from two different communities of allied schools that deployed similar solutions and that found professionals from non-allied schools collaborating.

Replacing and Expanding a Learning Management System

Northern Middle and High School enrolls approximately 300 students in grades seven through 12. Most students who attend Northern attend one of two allied elementary schools. Three years prior to the initiation of this project, Northern had begun a one-to-one initiative, so it was undertaken in the first year that each student in the high school grades (nine through 12) had access to a laptop computer.

Coincident with the beginning the one-to-one initiative, teachers started using a proprietary learning management system (LMS). The version of the LMS used by the school was free to use, but had limited functions; it was not transparent, thus is was not open source (Baker, 2017). The principal articulated the coincident goals of the LMS and one-to-one initiatives, "with the one-to-one computers, teachers will use [the LMS] post materials so we can replace textbooks. They can lead discussions and share files for creative purposes, and move towards online materials and collaboration." He recognized, however, this had not been realized. The LMS had been adopted by about half of the faculty, but it served primarily as a digital drop box for and a file repository. The principal recorded a conversation during which "students said their online classroom was 'like a big filing cabinet for handouts' and they usually printed files from the site or they uploaded files the teacher printed out to grade." The principal further pointed to questions posed when broken copier which also served as a scanner broke; teachers asked, "How are we supposed to get out handouts online if we can't scan them?" For the principal, the LMS should, "be a space where students and teachers interact and collaborate, but this is not happening." It was clear the LMS was being used, but not in the intended manner.

It was not clear from the documents available if the limited use of the LMS by teachers was the result of the limited functionality of the version they were using or if the functions were available, but unused. The decision to replace the free version of the propriety LMS was motivated the discovery that an online classroom had become corrupted and work was lost. Because they were using the free version of the LMS, there was neither a backup copy of the course nor was the school entitled to technology support from the provider. After that incident the principal reported, "we need a more professional system so this does not happen again." In replacing the LMS, the principal insisted "it be flexible so teachers can do more things with students online, plus they need to be able to share assessment rubrics with others, and we need backups to prevent loss of work." It was clear the cost of subscribing to the proprietary LMS at the level necessary for support and flexibility was beyond the budget, so the principal accepted the recommendation that and open source solution be deployed.

A design/ construction committee comprising two teachers who had been using the proprietary LMS, the technology coordinator for the allied schools, and the author was convened to recommend a replacement LMS. At the first meeting, the technology coordinator resigned from the group reasoning, "I have no time, budget, or server resources to dedicate to this project, and other projects need my attention this year." He did recommend to the group, "Get a web hosting service that meets the system requirements, install the LMS you want, and have teachers manage it all." The reduced committee advised the principal to purchase space on a virtual private server (VPS) with storage, bandwidth, and processing that exceeded the estimated need and that fell within the budget identified by the principal. The committee also

reviewed the features of several open source learning management systems. The demonstration sites all appeared to provide the features we want and could be installed on the VPS service we recommend. The committee suggests we install Moodle, because the three people on the committee all have experience using it.

Within one week, the principal had secured space on a virtual private server, and the author had installed Moodle (Version 2.7) (Moodle, 2014), an open source learning management system that is widely used in both K-12 and higher education, and configured the database. As an initial test, committee members confirmed: a) the Moodle site was available from the school's network, b) it was available off-campus, c) teachers could create courses, d) several users could administer the site. Once the initial

test was successful, the two teachers on the design/ construction committee began using Moodle with their students. Within days of learning it was available, three teachers (who were still using the proprietary LMS) requested access to Moodle. This was granted, so the test installation and the committee participating in its development quickly expanded.

The design/ construction committee now comprised five teachers, and they recorded observations of Moodle before reconvening to "discuss changes to Moodle before extending the pilot project any further." The first recommendations focused on navigation and appearance. The teachers reported that students complained about the appearance of the site and found it "hard to use," but those complaints dissipated as students became familiar with the interface. One teacher observed, "I can't see the menus without scrolling and I can't see the names of students who posted in the discussions" The committee was able to resolve the navigation problems by changing the theme which controlled the appearance of the site (including the behaviors of menus and discussion boards).

The committee also recognized Moodle allowed more sophisticated grading than the replaced propriety LMS. While teachers wanted to use those features, they felt unprepared, so they shared a word processing document on which they recorded the steps to filter submissions, display a single individual's assignments, update grades for multiple students at once, and otherwise manage grades. One teacher also described a feature she had used at another school that allowed teachers to add comments to portable document format (PDF) files that students had uploaded. The plugin that added the PDF mark-up functionality was located and the author installed and configured it.

Less than one month after the initial test of Moodle, the first redesign/ reconstruction iteration was complete. By deploying a different theme, the committee improved navigation of Moodle for all users within minutes by editing the settings that were provided by the producers. Using advanced grading features was developed over several days and included both the deployment of a new plugin (a technology solution) and effort by teachers to share new learning (a non-technology solution).

About four months into the project, it had expanded to a total of eight teachers and over 100 students who were enrolled in more than 20 sections. It was nearing the end of the school year, so the principal asked for recommended next steps. The teachers described the minor changes that had been made to the installation of Moodle during the first iteration. When asked directly about the original goals of using more advanced features of the LMS, the teachers shared examples of threaded discussions, embedded media, and examples of PDF assignments with comments; none of which had been used on the replaced LMS. Convinced it was used for more types of activities than the previous LMS, the principal charged the committee with "rolling this out so the whole school can use Moodle when we return to school at the end of summer."

Meeting minutes indicated the committee members were satisfied the functionality of Moodle met the previous uses of the LMS (a drop box and a collection of shared files) and advanced features were sufficiently understood and supportable that the Moodle could be "promoted to teachers as the 'new and improved' online platform." The committee noted, however, "students have too many usernames and passwords—the network, their email, the student information system, and now Moodle", so it recommended, "a single sign-on is necessary so students do not have to remember another username and password, and teachers don't have to know how to reset them." It further recommended, "allowing self-enrolling in Moodle courses, so teachers don't have to 'do all of that clicking' to get students in their courses."

Both of those recommendations were incorporated into the next design/ construction iteration. Another plugin was added to Moodle to allow users to log on using their Google Applications for Education accounts, which were already used for other purposes by both teachers and students. To address security

concerns, only accounts controlled by Northern Middle and High School were allowed to be used to log on to Northern's installation of Moodle. The configuration of Moodle was also changed to allow authenticated users to self-enroll in courses; when teachers returned for the start of school, they were given directions on how to utilize this feature.

At the same time the LMS replacement was underway, the faculty was undertaking a separate initiative to add authentic learning (Herrington, Oliver, & Reeves, 2013) into the curriculum. Associated with that initiative was the decision to replace the existing electronic portfolio platform. A group of faculty who were working on the authentic learning initiative met with the Moodle committee. The first meeting of this combined committee found the team returning to the explore/ analyze phase of educational design research. The combined committee articulated the goal of "designing a single online space where students' work could flow easily between the online classroom and the online portfolio."

During the initial design/ construction iteration, the team identified Mahara (Mahara, n.d.) as an open source portfolio platform that that could be installed on the same virtual private server use to host Moodle. Once the system was installed and configured, the combined committee spent time "sandboxing, so the teachers can determine it Mahara fits the assessment and data collection needs of the authentic learning initiative." After they concluded Mahara provided the necessary portfolio functions, the combined committee directed the author to configure Mahara so that students and teachers could use their Moodle accounts, which were actually users' GAFE accounts, to authenticate into Mahara. This configuration also allowed for documents and portfolios to be shared between the two platforms.

Northern Middle and High School's full development of the Moodle/ Mahara system began with an initial decision to replace the proprietary LMS, this decision was made to improve the performance of the technology and to provide more flexible teaching and learning. Several iterations of design/ construction based on users' feedback made the LMS easier to use and expanded its functionality while easing management. Further design/ construction iterations resulted in the LMS and the electronic portfolio system being integrated so that they appeared to be a single system. In each step, the combined Moodle/ Mahara complex more closely reflected the teaching and learning goals the principal had originally articulated.

Algebra 1 at a Distance

Dan is the principal at Crossroads Elementary School which enrolls just over 100 students in grades K-8. More than half of the students who attend the school live in the village that extends about one mile in each direction from the intersection where the school is situated. Most of the other students live on the farms that are scattered throughout the town. He recognized, "the community takes great pride in nurturing young people and providing excellent opportunities, but the tightening budget and some personnel changes have made continuing that tradition very challenging."

One particular problem was providing Algebra 1 for the students who were ready to take that course for high school credit. Dan explained the process recently adopted by the allied high school, "students can take Algebra 1 in their home school, but they take the same final exam as the high school students. If they pass, they get credit, if not they take it again." In the letter that explained the new policy, the principal of the allied high school and the chairperson of the mathematics department had explained, "we need more control over who enrolls in advanced mathematics courses."

Dan further described the situation in which he found his faculty, "We have one science and math teacher for our middle school. Her schedule was full and we had three kids who were ready for Algebra, but we had no teacher." When Dan learned an allied K-8 schools had hired a new part-time math teacher

who was very experienced, he contacted the principal and asked how his students might be able to access that teacher. With the cooperation of the curriculum coordinator who was shared among the allied K-8 schools and the high school, Dan arranged for the schools to teach eighth grade math at a time that coincided with the Algebra 1 class taught by the new math instructor. At Crossroads Elementary, the instructional problem was summarized as, "Providing Crossroads students access to a highly qualified Algebra teacher who teaches at a location other than our school," and the "instruction is to be synchronous."

The first solution to having remote students participate in the Algebra 1 course was to set up a web camera in the classroom where the teacher was and to use a free, but proprietary, video chat tool to connect the teacher with students at Crossroads and the other schools. It was clear during the first session, however, it was not an adequate solution. Dan observed the first session and noted, "all of the students agree they cannot see the board well enough and there is little chance for them to ask questions. Plus, the teacher had his back to the students much of the time." The technology integration specialist employed by the allied K-8 schools observed the session from a different remote site and confirmed students at that site had the same experience. Dan noted, "this solution will not work for our students. We need another way for kids to work with [the Algebra teacher]." The initial design/ construction iteration in this case was deemed a failure; so it was immediately abandoned.

Dan convened a group (the composition of which is unclear) to reopen the analysis/ understanding of the problem of, especially to reexamine the need for Algebra to be taught via synchronous meetings. That group asked the author and the technology integration specialist to "test other technology systems that will resolve the connections between the teacher and the remote sites, specifically: a) unclear transmission of visuals, b) unclear transmission of spoken information, and c) lack of two-way communication between the remote sites to the location of the teacher." It was proposed that sites be connected through a video conferencing tool rather than simply a camera, and the author and the technology integration specialist suggested, "screen sharing, an open audio channel between the sites, and reliable chat between the sites will improve interaction."

The next iteration of the design/ construction of the video conferencing link connecting the K-8 schools found a group of people at each location for a "test activity in which we will try to replicate an Algebra lesson, but with a focus on refining the system rather than learning math." At each site, one of the students taking the Algebra course, along with the school's principal, connected to a video conference that was initiated by the Algebra teacher from his school. The technology integration specialist was at the site with the teacher and the author was at Crossroads. The connection was established using a free to use version of a proprietary video conferencing platform. Further, the remote Algebra teacher had constructed a system whereby a digital camera pointed at the whiteboard where he wrote.

Upon completion of the trial, Dan and the student at his school concurred, "this is a much better system. We could see and hear what was said and written and we could ask questions by both chat and speaking." The individuals who participated at all of the sites further concurred that several practices needed to become standard for the course, including "a) sites need to mute their microphones unless they are speaking, b) the teacher needs to watch for chat requests, and c) there needs to be a seamless method for switching between the white board camera and the camera on the computer." While the video conferencing platform was deemed an improvement over the web camera, the arrangement of the digital camera and whiteboard was determined to need further improvement before the system was used for teaching and the limits placed on users of the freemium software were deemed to pose a significant obstacle to its effective use. Prior to using the system to teach Algebra again, the author and the tech-

nology integration specialist along with the teacher completed a second design/ construction phase in which two changes were implemented.

First, the team (in collaboration with the technology coordinator employed by the allied school) deployed Jitsi (n.d.), an open source video conferencing platform. Tests of this platform determined it appeared to resolve the video, audio, and interaction problems that prompted the decision to abandon the original web camera solution. Second, the video transmission of the visuals drawn on the whiteboard were improved by devising a method whereby a camera was poised over a whiteboard on a table where the teacher wrote and drew. The method of viewing the whiteboard through the video conference was even adopted by the students in the room where the teacher taught, so they would connect to the same video conference and watch the same whiteboard presentations as the students at the remote sites. The teacher also reported the students in the classroom with him began using the same chat channels to interact as the remote students, as well.

Unlike the case of Northern Middle and High School, in which the feedback that led to design/ construction decisions were largely informed by students and teachers who were actively using the systems for their work and which took place over weeks, Crossroads and its allied schools made decisions based on small groups of users who tested the system prior to its being deployed again. Dan noted, "the web camera thing was terrible, we needed to fix all of it before we tried it again." In the notes he kept as the system was used in the following months, Dan further noted, "as the teacher got better at using it, the lessons seemed to flow much better and students and got better at asking questions using the chat feature."

Two unpredicted outcomes arose from this project. First, the chairperson of mathematics department at the allied high school attended some distance Algebra classes by connecting to the video conference, so it had more oversight by the high school mathematics department than had been reasonable previously. She noted, "We did not want to be intrusive, but we wanted to be sure student were getting what they needed because we were essentially giving credit for what happened in those schools. It worked well, and we even had some of our students participate in some of the sessions." Second, the teacher began recording parts of the sessions and those became a resource for several purposes including a collection of worked examples and posted them for students and parents to use as a reference during homework and they became a focus of professional development for the mathematics teachers at the high school.

Supporting New Teaching via Online Classrooms

Peter is the assistant superintendent for an alliance of six schools that extends "more than 25 miles from end to end," and Joan is a part-time technology coordinator working in an adjoining alliance of four schools including three small elementary schools. In each of those jurisdictions, curriculum initiatives were underway. Peter was engaged in an initiative to increase problem-based learning in all grades, but especially in the secondary grades. Joan was engaged in an initiative to refresh technology-based teaching and learning to coincide with the arrival of new Chromebooks in the elementary schools. This project started when the two began to collaborate with the author to support teachers' learning.

Both Peter and Joan sought to include teacher-leaders to provide leadership to their peers. One of the teacher-leaders from Joan's schools described the problem and her motivation as "finding technology resources that are appropriate for my students, we have been inheriting old technology from the high school. Now, we get new stuff and we want to show what we can do." Joan explained that most of the computers in the district's elementary schools had been "hand-me-downs from the high school, but a

new superintendent insisted the elementary students get better technology to use." A teacher-leader in Peter's high school said he had been motivated by "the excessive focus on standardized testing, and the need to give students the chance to dig deeper into our subjects." These two projects had similar goals as they both sought to support teachers who were developing previously untaught curricula and using unfamiliar methods and tools; the support was to include both access to instructional materials and collaborative development of teaching methods.

Peter's district had been using Moodle to provide online classrooms for students; Peter explained,

most of our teachers were at least familiar with Moodle and used it for at least some things. Middle school and elementary teachers less so than high school, and we wanted them to use it more, so we decided to start an online classroom dedicated to project-based learning and we enrolled all of the teachers in it.

Joan described her decision to follow a similar approach to Peter's, "when I heard what they were doing, I decided to steal the idea, and Peter's 'tech guy' was very helpful in helping me get Moodle up running much quicker than I could have because I am only part-time." For the teachers in Joan's schools, this would be the first and only use of Moodle in their professional lives; she noted, "when this was introduced at a faculty meeting, no one said they had used Moodle before. Some younger teachers have done some online courses in college, but it was very limited." The first iteration of the design/ construction phase concluded when Joan's schools had Moodle installed and teachers could access a classroom for teachers to "explore how the Chromebook can help you teach and share ideas."

Because Joan's teachers were using Chromebooks, many of the materials they shared on Moodle were links to web sites. One problem they soon encountered was reported in an email sent to one of the teachers-leaders; "the sites are great, but the list is getting too big and it is kind of disorganized. It takes too long to scroll through them and it would help if we could keep some notes on them, so we know how to find the ones we need." Teachers in Peter's schools encountered a similar problem. A teacher recorded, "We share good sites, like [an art museum's] online collection, but it would be more useful if we could see just the stuff we need for our classes." Joan and Peter identified "finding an easy method of organizing the materials on the Moodle site, so users can quickly find what they need" as a problem that needed to be resolved through design/ construction. Peter and Joan each assigned one teacher-leader to collaborate to find a solution. That pair of teacher-leaders met with the author to explore different options for categorizing or filtering materials in Moodle. The group prepared three different options; specifically, they demonstrated a) adding tags to items using that feature which is part of Moodle, b) organizing materials into folders, and c) organizing resources with a wiki. Screen recordings of each method were posted on the World Wide Web and teachers in both jurisdictions were invited to review the methods. One week later, the teacher-leaders hosted an afterschool meeting in two locations (one in each jurisdiction and connected via a video conference tool) at which teachers discussed the method they preferred.

In the report to Peter and Joan that followed that session, the teacher-leaders noted, "The teachers recommend tagging as the preferred method for organizing resources. The primary reason was the ease for teachers—they just type the words they want to use or they select from existing tags." In addition, the group had expressed concern over the potential of a teacher deleting items added by others. The teacher-leader from Peter's schools met with the technology coordinator who served those allied schools, and

who had the greatest experience administering Moodle of anyone in the group, to discuss the concern about teachers editing or deleting items. The teacher-leader reported, "solutions were possible, but we concluded any changes were too much work to develop and test. Basically, we just need to be careful, and if [accidental deleting] becomes a problem, then we can worry about preventing it."

In the weeks after tagging was introduced as a strategy for organizing resources, the pair of teacher-leaders worked within their schools to ensure teachers knew how to tag; concurrently, they asked teachers to cull and tag the remaining resources. One of the teacher-leaders recorded, "Mrs. Smith was a teacher who was overwhelmed by the disorganized resources, but she is now using tags and is always reminding others to add tags. The site is much more useful to her now." Although there are no other data regarding teachers' perceptions of the process or the value it added to the collection in either jurisdiction, in October 2016 Joan and Peter tallied the 50 most recent additions to the Moodle site he or she manages and at least 45 on each had been tagged with at least one term.

As project-based learning was becoming a focus of teaching in his schools, Peter had led many in-person curriculum development workshops to introduce the method and to provide teachers with experience in preparing materials. As the initiative entered its third year (which was the first year that Moodle was introduced to support the work) teachers were becoming increasingly independent in the work and found others' input on their ideas helped, but the face-to-face sessions seemed less important. Peter observed, "teachers are impatient with the time to schedule face-to-face reviews, so they wanted to move that work online." Peter described how "teachers started a forum where they posted projects they were thinking about and they gave each other feedback and found connections between the projects in one subject areas and those in another."

Because Joan and Peter communicated frequently on this work, Joan decided to add forums to her installation of Moodle as well. Joan sent an email to teachers indicating she had added a "forum for questions and answers about how to use the Chromebooks in classrooms." About a month after the forum was added to Moodle, Joan noted there were fewer than five posts on the forums and none had responses. Peter observed a similar situation when his schools first deployed forums to Moodle, "three of our teachers were absent from the forums. It turns out they were unsure of what to do. But after a tutoring session, they were participating along with the others." Using this as a cue, Joan decided to provide a brief in-person training session in how to use forums for teachers in her schools. Immediately afterwards, she noted far greater participation in the forums, with teachers posting suggestions, asking questions, and answering others' questions.

In the case of online professional development in these two jurisdictions, several iterations of design/ construction led to an improved online environment for teaching and learning. The decision to adopt Moodle for professional development purposes by Joan and her school was largely informed by the similar decision made by Peter and the collaborative relationship Joan and Peter had established. In the same way improvements to the LMS at Northern Middle and High School were made in response to feedback from individuals who were actively using the system, Joan and Peter convened groups to design/ construct solutions in response to the feedback from active users. Using that feedback to identify deficiencies in the configuration or the manner of professionals' use of the system, decisions were made and improvements were deployed.

FINDINGS

This final phase of educational design research (McKenny & Reeves, 2012) is evaluation/ reflection. This finds researcher-practitioners evaluating the work to determine if the intended outcomes were realized and also to articulate generalizations that can inform their further work in the field, that can be applied by others in other settings, or that can be applied to different problems. The data from these cases support generalizations with regard to the use of educational design research as a strategy to inform planning decisions and also the application of open course technologies to the support of teaching and learning in rural schools.

Educational Design Research as Technology Planning

Educational design research (McKenny & Reeves, 2012) is simultaneously a research methodology and a method for designing interventions. In the semi-structured interviews conducted with the school leaders who initiated these projects that were conducted in 2016, the leaders where asked about educational design research as a method of designing interventions. In each case, the leaders differentiated these planning processes from those they typically employed. They identified these as more satisfactory than others and described specific aspects of educational design research that appeared to contribute to the value of the interventions. There is evidence the improvement are grounded in the iterative nature of the process and in the clearly defined roles of different individuals in the process.

Understanding Improvement

Researchers adopt an objective stance towards the measurements they make and the data they analyze and interpret; through objective analysis, they seek to use evidence to support and elucidate theories that accurately predict and explain observations. In contrast, designers of interventions adopt a subjective stance towards data; designers seek to achieve outcomes that are defined by the designers or others, and data is interpreted to ascertain the degree to which the outcomes were achieved. While there appears to be a contradiction in these two approaches to data and evidence, there is a tradition of applying research methods, including sophisticated data collection and analysis procedures, to the design of interventions.

Bereiter (2002) described progressive discourse as a planning method that is simultaneously grounded in a research and intended to improve conditions. For Bereiter, progressive discourse depends on a shared understanding of activity that will constitute the intended outcome (simply agreeing on language is insufficient), and interventions are defined and refined so that what is observed more closely resembles what the planners want to observe. Like progressive discourse, educational design research (McKenny & Reeves, 2012) is intended to be iterative and improving; planners deploy an intervention, observe its effect, then refine and redeploy it so that its performance improves according to the designers' perceptions.

Dan, the principal who initiated the Algebra at a distance project, contrasted the planning he was taught as a graduate student to the planning he experienced in this project. "I was taught planning was a step-by-step process. Once you have a goal, you plan to meet it, then decide if you met it. It is step at a time and slow," but he observed in this project "we failed at first, we quickly went back to much quicker planning than I am used to." Dan further described how the iterative processes were connected, and the first failure helped to revise his understanding.

I knew we wanted 'a good way to have our students take the class, but I didn't really know what that meant… I thought I did… but it wasn't until I saw how bad our first solution was that I could break it into the parts.

For Dan, the lens of the failure was essential to defining improvement, "Once I saw the bad images on the screen, I knew what we needed to improve."

It became immediately clear to Dan what would constitute improvement, but for other leaders, the improvements were less obvious at first. The principal at Northern admitted the problem was originally unclear in his school; "using online courses to replace textbooks and the authentic learning stuff we were doing were both good ideas—teachers were on board the community was too—but we really didn't know what it was going to look like." Because the initiatives were unfamiliar to most faculty, there was little agreement about the technology capacity and functionality necessary. "For us," he said, "we moved from non-technology to technology," and he clarified that with the example of electronic portfolios,

we talked about what we did [previously] and what we wanted to do with portfolios to document learning, then we looked to the tech people who were on the committee to build it. Our work then became better organized as we followed the procedures for using the technology.

In Northern Middle and High School, the activity of compiling portfolios to document students' authentic learning was improved by the process of designing a technology solution for that work; specific improvements included more teachers documenting more work than had been done previously.

Iterations

The iterative nature of planning the followed educational design research (McKenny & Reeves, 2012) also changed the approach to planning experienced by these school leaders. The principal at Northern described how iterations were essential to the progress and improvements that he observed as the proprietary LMS was replaced and as the open source LMS was configured to provide better service. He noted, "Our school had a long history of making technology decisions, but then never revisiting them. The response from the technology coordinator was always, 'I built what you asked for, it is your problem you didn't ask for the right thing.'" The principal described a sense of relief when that technology coordinator removed himself from the LMS planning process, "the committee had permission to keep working and keep fixing until it was right which is important in education, because you can't always know what you will need until you are using it with students."

For Peter, also, the explicit nature of planning that followed educational design research led to iterative and continuous planning. "Too often, we try to change things all at once in education and that can be uncomfortable for teachers," Peter said. He contrasted that with how the Moodle classrooms had been refined in his schools. "We started with one step, and when it got to where it wasn't working the question we asked was, 'how do we improve what we have?' rather than 'what do we replace [Moodle] with?'" Joan concurred with the view of the manner in which Moodle was implemented and she described the approach as "a slow process, but it never restarted. Once teachers were comfortable, we took the next step. It is unusual to improve professional development slowly with each step 'a step up' from where we were."

The Need for Expertise

The open source technology solutions deployed in these cases were all designed to improve the use of technology for teaching and learning. Educational technology is a multidimensional aspect of school planning and it requires expertise in multiple areas to be effectively deployed. In each of these cases, technical expertise was needed to identify and initially evaluate then install and configure open source software. Much of the feedback that informed the iterative design/ construction cycles originated in observations and criticisms from teachers or others who lacked the technical expertise to reconfigure the technology, but whose experience using it was deeply connected to how it was configured. In these cases, effective open source solutions resulted from systems that were properly configured by those with technical expertise and appropriately configured to reflect the needs of teachers and learners.

The lack of sufficient technical expertise appears to be an impediment to the improvements that were illustrated in these cases. The one principal who was interviewed, but who abandoned the project she had initiated fewer than 18 months previously noted, "we used Moodle for curriculum development work and it was great. Our part-time technology person made some changes to it, but something went wrong. He found a full-time job, and he wasn't able to fix it before leaving." She did contrast managing content and courses with configuring Moodle; "we had a teacher who had been doing lots with Moodle try to fix the problems but there was a setting that he could not figure out, so we switched our work over to Google Drive so we could get better technology support." For that principal, access was limited by the expertise necessary to perform the duties; she was unable to secure an individual with the necessary knowledge given the time and salary limits of her budget.

Access to technology expertise is also a challenge to Joan's initiative, but the access appears to have been in time, not knowledge. She observed,

Working with [the technology coordinator from Peter's schools], I have learned how to manage Moodle. It was not much different from the work I have done for years as a web master for schools, but I just don't have the time to tend to problems in a timely manner.

These data also appear to confirm the need for greater levels of technological expertise in communities using open source tools compared to those using proprietary tools (Kimmons, 2015). Budgets limit the level of expertise that can be hired in some rural communities; while in others, individuals with sufficient expertise have other duties or reduced schedules which limit the degree to which their expertise can be used.

Collaboration Among Experts

Stefaniak (2015) noted the tendency to perceive educational technology to be primarily technical in nature, so projects and improvements are assigned to technical experts. Once technologists assume responsibility for a project, there tends to be a sharp boundary separating educators from technologists who receive little oversight from school leaders. This can contribute to a challenging situation in schools where the individual with the greatest expertise in implementing technology changes are the individuals with least experience using it with students, so the systems they build or the changes they make can pose an obstacle to students' use of technology. Wegner, White, and Smith (2009) observed the most

effective technology leaders are often those whose experience is based in the operation of the organization. As was demonstrated in these cases, effective technology was designed only with the input of both educators and technologists.

When the faculty in Peter and Joan's schools identified the need to organize resources on the LMS, a small number of teachers with greater than usual technical skill collaborated with the author (who served as a technology expert) to develop three potential solutions. After the potential solutions had been tested, they were presented to the full faculty to make the final decision. In this way, there was a division of labor that led to improvement, but the division was collaborative as the final decision was made by the teachers and it was further refined following their feedback. The committee that met to develop those options was charged with "bring to the committee multiple methods of organizing the things teachers add to the site, so the teachers can agree on the one that seems best." Peter recorded, "the resulting collaboration worked—people with tech expertise built [the solutions], but the teachers selected the best one." These are examples of how collaboration between educators and technologists produced a solution that was both easy and effective for the teachers and easy to deploy for the technologists.

The principal at Northern recorded a similar observation early in the planning of the initial LMS project. "It is probably good that [the technology coordinator] is not on the team. He is known to build what we first say we want, but then to react badly when the plan changes." The principal compared the typical progress with technology projects with sharp divisions of labor to the work that led to the Moodle-Mahara system, "We needed both tech people and teachers to get this to work… and they needed to listen to each other and to change their thinking based on what the others were saying." At Northern, the iterative and collaborative nature of the planning allowed for an effective solution to be developed by excluding an individual who had avoided collaboration in the past; the principal noted, "when [the technology coordinator] resigned from the committee before it even met, his excuse was [a lie,] but it was good that he understood he would not do well on that team."

In these cases, the decision that led to new cycle of design/ construction decisions were informed by educators who sought to improve or expand the function of the technology systems. Technologists were largely responsible for configuring the systems to reflect the design/ construction decisions, then the solutions were evaluated by educators before they were deployed for all users. The role of the teacher-leaders whose recommendation led to organizing resources in the Moodle installations deployed by Peter and Joan via tagging explained, "School administrators left it to us, as long as it worked, they wanted 'hands-off.' We sat with [the author] to research options on the Moodle site, then configure them, but if teachers didn't like it, we would fix it."

Open Source Technology in Rural Communities

The projects undertaken for this study were designed to improve technology-rich teaching and learning in schools located in rural areas. Because the solutions made us of open source technologies, which are available at no cost to users, the findings regarding the successful development of the tools are of particular interest to educators in rural areas. The decision to use these tools is likely to alleviate some of the financial challenges faced by school and technology leaders in rural areas. Further, the nature of the technology use and the changes in educators' interaction with these tools indicate educators may become more sophisticated users of technology if they are deployed in a collaborative and iterative manner.

Technology Acceptance

Technology acceptance model (Davis, 1989) was first elucidated to identify the factors positively associated with the decision to use technology; it was later combined with eight other theories the predict technology use into the unified theory of acceptance and use of technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003). In general, technology acceptance predicts tools that are perceived to be easy to use (high effort expectance), effective (high performance expectancy), and that is used by others (high social expectancy) are more likely to be used than tools that do not demonstrate these characteristics.

Two decisions captured in this data support the observation that effort expectancy is influenced redesign decisions. In the case of Northern Middle and High School, the selection of Moodle (and then the subsequent decision to install Mahara) was motivated by the fact that the systems could be connected to students' existing accounts on the Google domain already managed by the school technologists and used daily by the students. The principal described his observations of students' work in classes using the replaced LMS, "before we rolled this system out, I watched teachers spend 20 minutes getting passwords reset because they forgot them, and it was a system not everyone used—in part because of the password problems." Although there is no evidence that his "20 minutes" assessment is accurate, it does capture effect that using a single-sign on exerted on increasing effort expectancy, thus improving the system.

Ease of use also contributed to expanded use project-based learning and other authentic learning activities at Northern. Some resistance from teachers to incorporating authentic assessments was that grounded in the perception that documenting it was too much work and it was done inconsistently by teachers. The principal described how authentic learning was documented prior to the Moodle-Mahara system,

we used to take pictures of projects, but some teachers put them on a server, others used [Google Drive,] and still others did who knows what. When we had students try to compile a portfolio, it was a mess trying to find everything they needed.

Dan described how ease of use affected the distance-based Algebra course at Crossroads Elementary School, as well.

One of the challenges we faced as the course progressed was testing. We started out scanning tests to the teacher, but that was a very slow process. The Algebra teacher worked with some of his former colleagues to learn how to use the free version of [a propriety learning management system] for online tests. It was much easier to have students just go take tests online, but we kept scanning the projects and more challenging problems he had them do.

The decision to recommend tagging as a means of organizing content in the LMS's provided for professional development in the schools led by Peter and Joan also supports the observation that perceived effort expectancy is associated with the intention to use technology. The primary decision to adopt tagging was made because it was going to be the easiest of the three options for the teachers, and Joan noted, "one of our teachers who was reluctant to use the site at first now introduces it to new teachers and she tells them all the time how easy it is to use."

A second factor associated with increased use of technology according to UTAUT (Venkatesh et al., 2003) is performance expectancy; that factor is grounded in several characteristics including job fit. The principal at Northern described a situation in which the technology influenced teachers' curriculum decisions in a manner that was perceived as improvement by school leaders. He observed "teachers can have students create portfolio pages, then hand them in on Moodle, so there seems to be a stronger connection between the projects in portfolios and the content of the courses." With the greater amount of authentic learning being compiled in the system, the principal observed, "we are taking it more seriously, and finally having conversations about broad learning expectations that go across all courses," and he also noted, "we seemed to be struggling with both authentic learning and using the online classrooms, but once both were built and connected, there has been increased use of each."

UTAUT (Venkatesh et al., 2003) further posits that use of technology is increased in those instances in which there are strong social influences. Specifically, one is more likely to use technology used by others whose opinions are valued. In these cases, this was illustrated in the active role of teacher-leaders in Norther Middle and High School and in Joan's and Peter's schools. When asked about the quick spread of the initial tests of Moodle in his school, the principal at Northern said,

looking back, that was important, the few teachers who started using Moodle were really mentors to others, and they just started sharing without me or anyone else telling them to. Others saw what they were doing and wanted to join the club.

Joan noted the importance of the teacher-leaders in the wide adoption of the Moodle site to support Chromebook-based teaching in her schools as well. "I knew I could not be the full time leader and principals were all too busy, so I thought carefully about the teachers who I asked to be leaders." Joan detailed the characteristics she wanted in the teacher-leaders, "They needed to be perceived as strong teachers, have technical skill, and be able to work with colleagues in a patient manner."

Teo (2011) observed, "teachers spend much of their planning time to consider how technology could be harnessed for effective lesson delivery and assessment" (p. 1). In these cases, there appears to be support for the conclusion that planning can be more efficacious and solutions perceived to be improving if they are designed to increase factors associated with technology acceptance.

Participatory Cultures

In 2009, Jenkins and his colleagues defined participatory cultures as those "with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing creations, and some type of informal mentorship whereby experienced participants pass along knowledge to novices" (p. xi). While Jenkins' participatory culture is largely understood to be a phenomenon of younger generations, scholars have identified an increasing expectation that users of digital information assume a more active role in creating and consuming information compared to those generations that experienced only print media and electronic mass media (Deuze, 2006). One of the defining characteristics of participatory cultures is the collaborative nature of the creative processes (Halverson, 2012). The interventions described in each of the cases in this chapter were produced by collaborative interactions among the professionals. All school leaders in the schools described this chapter played an active role in both initiating the

projects and ensuring they were adequately supported. Their active support included scheduling time for professionals to meet, arranging for the purchase of necessary materials and technologies, and ensuring other professionals participated as appropriate. Teachers ensured that the interventions were tested under appropriate situations and they gave focused and informative feedback to those with technological expertise who configured and reconfigured the open source technology to provide necessary functions.

Two of the cases described in this chapter appear to have contributed to on-going consumption and creation of open educational resources by the teachers who were initially engaged in them. The Algebra 1 teacher who taught remotely for students at Crossroads became interested in other remote teaching. Dan explained the teacher originally wanted to put recordings of his lectures online but the teacher decided against that; "he saw there was plenty of other good lectures online already, so he shifted his focus." Dan noted as well the Algebra course has shifted "from a traditional course just taught via video conference to a problem solving course." The teacher has created a web site to show students how to work problems," and "the video conferences have become students talking about complex problems and sharing their own solutions." In addition, the students are "using some new tools to show off their own solutions." In effect, Dan noted, "we have transitioned away from using the technology to deliver the content to using the technology as a place where students explore the content."

In addition, Dan described how the experience with Algebra 1 motivated him, along with the principals of the allied schools, to explore the use of the distance learning infrastructure for other projects. "We had a virtual science fair before the actual science fair, [students] discussed their projects before we all got on a bus and took the displays boards to [an allied school]" and "teachers get students together to discuss books on Jitsi." At Crossroads and the allied schools, the distance learning activities tended to be for specific projects, and each teacher adopted the platforms for single projects rather than as the primary method of instruction. Dan noted, "last year students did maybe five or six distance learning activities in different units in different classes. Teachers have shared the load without overdoing it, but students use distance learning in many contexts."

The teachers in Peter's schools discovered that textbooks were a weak resource for the authentic learning projects they sought to include in the curriculum; textbooks often did not provide sufficient coverage to meet students' needs when they researched topics of their own interest. In response, two of the teacher-leaders in Peter's schools began to explore open educational resources (OER) and to include resources from several open providers in their classes. Peter noted, "one science and one English teacher have become leaders in our expanded use of open educational resources." Their participation in the OER communities has expanded as well. While presenting workshops for their colleagues these two teachers illustrated the similarities between our use of Moodle and their participation in the extended OER communities.

Peter further described what he had observed in these teachers' classrooms, "the students were writing their own materials to repost to the OER site." According to Peter, this project appeared to be engaging students on multiple levels. "Some students were double-checking their materials against the novel to make sure details were accurate, but other students were working as copy editors." Peter also recounted the conversation he had with the teacher after the lesson, "he told me that students had become heavily invested in the work once someone downloaded an early draft of one piece [from the OER site] and they got some critical feedback."

DISCUSSION

Data reported in the chapter illustrate the use of decision-making processes grounded in educational design research (McKenny & Reeves, 2012) to develop and deploy open source technology solutions. The schools in which these projects were undertaken were rural, and demonstrated many of the characteristics of rural schools, including difficulties in staffing and limited access to support staff. These appear to have been limiting factors in previous school planning initiatives. Among the effects of these limiting factors were terminal interruptions to efforts toward school improvement. In these cases, there appears to be evidence that school leaders perceived interventions designed through educational design research (McKenny & Reeves, 2012) to have improved technology-rich teaching and learning, the improvements include both results that more closely reflect the intended outcomes and more sustained efforts to continue the improvements compared to previous planning strategies.

In addition to illustrating the application of design as an effective planning strategy, the data reported in this chapter appear to support several generalizations the are consistent with other findings. Hew & Bush (2007) observed technology integration, which they described as the use of computer and information technologies for instructional purposes, is a practice that is affected by many and interconnected factors. According to Hew & Bush, overcoming these barriers, and improving the level of technology integration is accomplished when barriers are identified and there is a strategy for overcoming them. Further, the strategy must be informed by a clear vision for technology which gives "school leaders and teachers an avenue to coherently communicate how technology can be used as well as a place to begin, a goal to achieves, and a guide along the way" (p. 234).

This research suggests that a vision is insufficient to completely support technology integration. In this data, there is evidence that the school leaders had a vision, but the iterative nature of this planning led them to clarify the vision and to guide not only the beginning place but also a strategy and framework that encouraged refining the vision and the improving the practices as technology was deployed. In addition to clarifying the problem, and contributing to effective evaluation of efforts, the method allowed school leaders to identify needs that previously would have remained hidden to them. The planning strategies provided a framework for how the work would proceed so the vision could be realized. In this way, the planning and decision-making described in this chapter supports the conclusion that iterative planning in which observation of activity is the data that informs further decisions leads to improved performance of the systems.

Davis (1989) observed that white collar workers did not always use technology that was available to facilitate their work. When originally elucidating technology acceptance model, he found that the intention to use technology was affected by several factors, especially the degree to which the user perceived the technology to be easy to use and to be useful. In 2003, Venkatesh, Morris, Davis, & Davis combined eight theories that had been used to predict technology use into the unified theory of acceptance and use of technology (UTAUT). UTAUT posits that technology perceived to be easy to use (high effort expectancy), useful (high performance expectancy), and used by others (high social expectancy) is more likely to be used than other technologies. While originally designed to predict and explain decisions to use technology in setting other than education, there is growing evidence that it describes the use of technology in these populations (Holden & Rada, 2010; Hu, Clark, and Ma, 2003; Smarkola, 2007) and also that efforts to increase technology acceptance can improve the degree to which technology is

used in K-12 schools (Ackerman, 2017; Straub, 2009). These data further support the applicability of technology acceptance as a heuristic for predicting and explain technology use in schools. Educators in rural schools tend to adopt multiple roles, and those school tend to have fewer resources to support professional development. When planning increased technology acceptance, the systems tend to be easier to use, thus reducing the need for training, so these data describe planning that will reduce the need for this already limited resource in rural schools.

A final conclusion that appears to be supported by this data describes the changing nature of educators' engagement with educational technology. Blumenfeld, Kempler, and Krajik (2006) define autonomy to include the "perception of a sense of agency" (p. 477), which arises from awareness and understanding of problems and solutions, as well as capacity and authority to implement solutions. The conclusion that educators exerted greater than usual autonomy in these planning efforts arises from the observation that the iterative process led to deeper understanding of the problem and the solutions than other planning efforts. Further, there is evidence in each case that the educators who were participating in the process had been given authority to make decisions. In these case of Northern Middle and High School's adoption of Moodle, there were budgetary limits placed on the decision to purchase space on a web server to host Moodle. In the decision to adopt tagging in Joan's schools, the teachers were given choice of limited options. In these examples, the authority to make decisions was limited by school leaders' decisions, but within those limits authority was given. There is evidence that teachers may exert limited autonomy with regards to regarding instructional practices (Range, Pijanowski, Duncan, Scherz, & Hvidston, 2014), however, so additional research in the emerging role of autonomy is necessary.

LIMITATIONS

The school leaders associated with these cases articulated differences between these planning methods and those used in other activities. Despite these observations, it cannot be determined from these data if those perceptions were the result of the planning methods or other factors. There are no data available to compare these planning efforts with those envisioned by the leaders when they identified differences. There is also no evidence that the problems solved in these cases would not have been solved using different planning methods. In each case, the problem was perceived to be real and efforts of multiple professionals were focused on solving it, so a sufficient solution might have emerged from any planning processes. Given the perceptions that educational design research was effective because it recognized improvement of students' and teachers' experiences as a worthy outcome, it was iterative, and it focused the work of the various types of experts in the design/ construction of technology-rich interventions; it appears those aspects of planning grounded in educational design research deserve additional inquiry.

This research also did not gather data regarding the application of planning methods derived from educational design research (McKenny & Reeves, 2012) to other planning problems encountered by the participants in this research. Schools are places where leaders constantly seek to make improvements. If this approach to planning was perceived to be more effect than other approaches, then it would be reasonable to expect these school leaders to have applied these methods to other aspects of school management. This study gathered no data to investigate other planning; it is also reasonable to expect evidence of this approach to school planning would be observed in other areas of school planning if the school leaders did find it more effective than other methods.

The data appear to support the conclusion that teaching and learning was improved in these cases. Improvement is a very difficult construct to define as it is based in individuals' perceptions, thus the same situation can be perceived differently by different people (Rittel and Weber, 1973). In these cases, improvements were judged only from the perspective of the school leaders who were both involved with the projects and were interviewed many months after the project began. It is unknown if the improvements were manifest in any other data sources or if the improvements were perceived to be improvements by other stakeholders.

The three cases described in this chapter are a subset of projects begun between 2013 and 2015; the author began collecting data for six projects when they were initiated, but only three met the inclusion criteria of being still active and under the original leaders. This research leaves unanswered questions regarding the sustainability of projects developed using educational design research. The three cases described in this chapter are still active, but they appear to have evolved since they were initiated. This research does not indicate what factors affected continuation and modification decisions. Data were collected from one of the projects that was abandoned, and it appears to suggest the lack of sufficient technical expertise contributed to that decision. It is unclear what other factors might cause a leader to abandon a project that was begun using planning grounded in educational design research. It is not known if the projects continued beyond the tenure of the leaders who initiated the project.

CONCLUSION

As illustrated in these cases, iterative planning undertaken to understand how a problem is instantiated and to design and deploy technology solutions appears to be and effective strategy for school and technology leaders. For professionals working in these rural communities, open source technology was deployed and efforts to improve instruction through sustained iterative planning were demonstrated.

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