Journal of Online Learning Research (2017) **3**(1), 31-54

Disconnected Data: The Challenge of Matching Activities to Outcomes for Students with Disabilities in Online Learning

MICHAEL W. CONNELL
michael.w.connell@gmail.com

SAM CATHERINE JOHNSTON
sjohnston@cast.org

TRACEY E. HALL
thall@cast.org

WILLIAM (SKIP) STAHL
sstahl@cast.org

CAST Inc., United States

Within blended learning environments, the availability and analysis of student data has emerged as a central issue. For struggling students, data generated by digital learning systems present new opportunities to investigate critical success factors. In reality, many seemingly basic questions about persistence, progress, and performance of these learners in online environments may not be readily answered using extant data. This research inquiry generated insight into the practical challenges related to data identification, acquisition, and analysis that are faced by stakeholders seeking to assess the impact of online learning environments on student outcomes. The intent was to investigate the feasibility of and identify barriers to creating a unified student record—that is, a single data set combining data on student demographics, activity, and academic performance drawn from different information systems—that might be used to identify salient factors associated with more or less successful student outcomes. This two-phase investigation highlighted key barriers that are important to address in future research efforts and engendered a series of recommendations that could eliminate some of the current challenges to data acquisition and analysis.

DISCONNECTED DATA: THE CHALLENGE OF MATCHING ACTIVITIES TO OUTCOMES IN ONLINE LEARNING

The Research Center and Its Focus

The Center on Online Learning and Students with Disabilities (COLSD), funded by the Office of Special Education Programs, United States Department of Education, conducts research on how K–12 online learning impacts the access, participation, and progress of students with disabilities in online settings (Basham, Smith, Greer, & Marino, 2013; Basham, Stahl, Ortiz, Rice, & Smith, 2015; Harvey, Greer, Basham, & Hu, 2014). These settings include full-time virtual schools, blended classrooms that combine online activities with attendance in brick-and-mortar classrooms, and supplemental courses for credit recovery or unique course enrollments. COLSD research focuses on the design, selection, and implementation of digital curriculum materials; the systems that deliver them; and the instructional practices associated with their use in order to increase efficacy for these students and other elementary and secondary learners participating in online learning environments.

In order to conduct ecologically valid and useful research in online instruction, COLSD has established multiple research to practice partnerships with school districts and large-scale online vendors who are presently engaged in online or blended instruction. The goal of these research partnerships is to identify the range of policies and practices—both promising and problematic—that presently exist in online learning and to conduct collaborative research that would guide future policies and practices to optimize student outcomes.

The research described here was conducted in collaboration with leaders from two of COLSD's Research to Practice partnerships: a non-profit online school (NE1[1]) offering supplemental high school courses and a for-profit educational technology and learning management system provider (NE2). NE1 and NE2 are already partnering with each other to provide services to diverse students and COLSD essentially acts as a third partner—a research partner—that brings additional capacity and expertise to conduct research that can benefit NE1 and NE2 as well as other providers like them in developing optimal services for students with disabilities and their peers.

Reports indicate that nearly every school district in the United States offers some form of blended or online learning and that hundreds of thousands of students are enrolled in full-time virtual schools (Barbour, 2013; Gemin, Pape, Vashaw, & Watson, 2015). COLSD research efforts targeting the approximately 6 percent of students with disabilities (Molnar et al.,

1 Pseudonyms are used for the two providers per the confidentiality terms of the research agreement.

2014) enrolled within these various online settings have attended to three interdependent factors: the students, the digital systems they engage with, and the learning context.

The research initiative that prompted this paper was designed to address these three factors via large-scale data collection in collaboration with NE1 and NE2. In reality, the data analyses fundamental to the research design proved too formidable to accommodate within the constraints of this particular project for reasons difficult to anticipate beforehand, where the challenges included missing data, inaccessible data, and uninterpretable data. While COLSD's charge was specific to students with disabilities, its researchers believe the challenges encountered are both common and generalizable across many existing elementary and secondary online learning systems and applicable to all students and that identifying them and offering some suggested approaches to eliminating them can inform future research efforts.

The Research Environment

In 2013–2014, NE1 (the online school) enrolled more than 15,000 students from 740 participating brick-and-mortar high schools in 200 secondary-level courses. From data provided by NE1, 200 of these students were reported as having Individualized Education Plans (IEPs), which may well be an under-reporting of the actual number of students with IEPs enrolled. As these exceptional students remind us, there is great variability among all learners; thus, instruction and curriculum for students should not follow a single prescribed trajectory through any online course (Meyer, Rose, & Gordon, 2014; Rose, 2016). Instead of asking "what works best?" in some global sense, it is important to consider the more nuanced research question, "what works best, for whom, and under what conditions?" A review of the literature and COLSD research indicates, however, that analysis of system usage data for informing educational practice in K–12 online learning is not yet the norm (Burdette, Greer, & Woods, 2013; Kim et al., 2015).

Research evidence substantiates that the analysis of large student data sets can yield correlations containing high predictive capabilities that are otherwise unavailable (Baker, 2010; Bienkowski, Feng, & Means, 2012; Markauskaite, 2011; Macfadyen & Dawson, 2010; Reshef, Reshef, Finucane, Grossman, McVean, Turnbaugh, & Sabeti, 2011). When data sets detailing student use of online learning environments are combined with demographic and student achievement data, in particular, profiles are identified that can be associated with a high degree of accuracy to learning pathways and decision-making (Davies & Graff, 2005; Zorrilla, García, & Álvarez; 2010). This, in turn, can expand the knowledge base for educators in two areas: 1) the identification of students on failure trajectories, and 2) the efficacy of targeted interventions designed to guide students towards more positive outcomes (Steiner, Hamilton, Peet, & Pane, 2015).

In online learning environments, therefore, the integration of three sets of student data—(a) demographic information about an individual student (such as age, disability status, and disability impact), (b) system usage (e.g., online activities, duration) and (c) academic achievement (e.g., grades, formative and summative assessment data)—has the potential to create new opportunities for understanding student learning, behavior, and progress, as well as for providing more targeted interventions for diverse learners (Hung, Hsu, & Rice, 2012; National Forum on Education Statistics, 2015; U.S. Department of Education, 2013). In order to realize this opportunity, however, each of these data sets must be examined not in isolation but in relation to one another. It is the variety of data challenges encountered while trying to compile such a unified student record—such as inability to obtain usage data from vendors and student demographic data from LEAs—that form the basis for this study.

In the NE1/NE2 inquiry specifically it was discovered that barriers exist at various points in the process—for example, data do not exist, the data exist but cannot be accessed readily, or what data do exist cannot be made usable for assessing meaningful educational impact at a reasonable cost, if at all. These findings were surprising since the cost-effective collection of large amounts of detailed data on student behavior is a primary affordance of *personalization* in online learning environments (Martinez, 2002; Romero & Ventura, 2010; Tanenbaum, Le Floch, & Boyle, 2013). In fact, there is evidence that while moving from offline to online learning environments yields much more operational data, existing challenges with accessing, sharing, and using data can in some cases severely limit the use of these data to inform instructional decisions for individual students or to inform improvements to the system as a whole to better serve particular groups of students like those with disabilities (Burdette, Franklin, East, & Mellard, 2015; Burdette, Greer, & Woods, 2013).

Based on the evidence that a correlation analysis of the three student data sets referenced earlier (demographics, usage, and achievement) can facilitate the identification of effective approaches to instruction by helping to identify factors associated with less than or greater than expected student achievement for specific subgroups of students, COLSD researchers initiated a two-phase approach to investigate what would be required and what barriers would need to be overcome in order to realize this opportunity.

METHODS

In Phase 1, COLSD researchers worked closely with the online school (NE1) and the school's learning management system (LMS) provider (NE2) in an effort to integrate student demographic, usage, and achievement data into a unified student record (USR) that could be analyzed to address research questions about students with disabilities (SWD) and their peers in online learning courses. An effort was made to collect and analyze data from three sources: quantitative student-level data extracted from the student information system (SIS) and LMS, interview data from key staff at NE1 and NE2, and examination of documents provided by the online school and its courses. This triangulation of data was used to explain the school's operational model and practices and what opportunities and challenges these practices generate for students (Cohen & Manion, 2000). While the full data set supported a number of different analyses, the current study focuses specifically on a set of challenges and barriers that resulted in relation to data collection, extraction, and analysis in an online environment. Additional descriptive studies of NE1 and NE2, including their models for supporting diverse students, as well as an analysis of challenges arising at the intersection between them are the subjects of separate papers (Connell & Johnston, 2015; Johnston & Connell, 2015a; Johnston & Connell, 2015b).

In Phase II, researchers again worked closely with NE1 and NE2 as well as with a third partner providing text-to-speech functionality (referred to here as audio-supported reading or ASR) to develop a technical specification for data collection and storage that would support the production of a USR. The intent was to implement that specification to produce the USR to determine if, how, and to what extent students used ASR support in an online course during an academic semester. By factoring ASR use into the analysis, researchers had hoped to identify the extent to which this support was associated with either greater than or less than anticipated academic achievement for different subgroups of students, although in the end, this analysis could not be carried out within the parameters of this research project, for reasons described in later sections.

Participants

COLSD researchers conducted face-to-face and written interviews with staff from both NE1 (the online school) and NE2 (the LMS provider). Interviewees were identified through a purposive sampling strategy (Patton, 2002). School staff at NE1 (n = 7), including senior managers and leaders across the functional areas of technology, instruction, IEP accommodations, and operations, were selected for participation. NE2 staff (n = 7) included leaders, managers, and individual contributors across the functional areas of technology, accessibility testing, instruction, research, analytics, marketing, and operations.

Design and Materials

NE1 and NE2 staff both independently guided researchers through one of their online courses to provide context around a typical student experience. Then each participant completed a semi-structured interview (Maxwell, 1996). This approach was selected to provide researchers with responses to a common set of questions while simultaneously allowing for more expansive reflections that could reveal further differences and similarities in how these two entities perceived and addressed online course design. Researchers also were granted access to the NE1 school course environment and NE2's LMS and examined features within the school's course environment designed to support student information access (e.g., text-to-speech).

A grounded theory approach was used (Glaser & Strauss, 1967) to analyze the interview data. Transcripts of all interviews were reviewed and independently coded by two independent reviewers. Codes for each interview were created during analysis of the transcript with each reviewer participating in the coding. Codes were used to summarize key areas discussed by the participants (Charmaz, 2006). Researchers worked through successive stages of coding and analysis, from the open codes and categories provided in the first stages to successively refined themes, to generate theoretical concepts and insights related to the research questions. Through this analytic process, the researchers identified and selected three theoretical concepts to analyze in depth:

- Task Structure and Competencies: The structure of tasks a student must engage in to learn in NE1 and the competencies they need to do so
- Role Structure: The structure of roles to support student learning in NE1
- Data Flows: The flow of data through the system from collection to interpretation to application in support of student learning

This study focuses on the third item—data flows—while the other two concepts are addressed elsewhere (Connell & Johnston, 2015; Johnston & Connell, 2015a; Johnston & Connell, 2015b). In Phase I of this initiative investigating data flows, the goal was to conduct a retrospective analysis of existing data—that is, student data that had been collected by the online school and the LMS provider in prior years. As such, the first step was to identify what kinds of questions might be answered given the available data. Interviews included questions about information and data systems; processes for collecting, storing, and using student data; and known barriers to using data effectively to support individual student learning. This, together with review of supporting documentation such as web pages where student data are collected, database specifications, and data dashboards and reports available to teachers, enabled the compilation of an inventory of key information systems and relevant data either stored in them or flowing through them (Figure 1). Based on this inventory, a wish list of demographic variables was compiled and a minimal set of demographic, usage, and achievement variables was chosen from among those that were confirmed to be used or logged somewhere in the system (please see Appendix A for a list of these variables and measures). The idea was to demonstrate feasibility with a minimal set of measures initially and then expand the scope to include more measures. In particular, the initial effort focused on compiling a USR containing student status (IEP, non-IEP), basic measures of student usage of the online platform, and course grades—all of which were data either stored in or used by the system. Researchers worked with the online school and the LMS provider to extract these data.

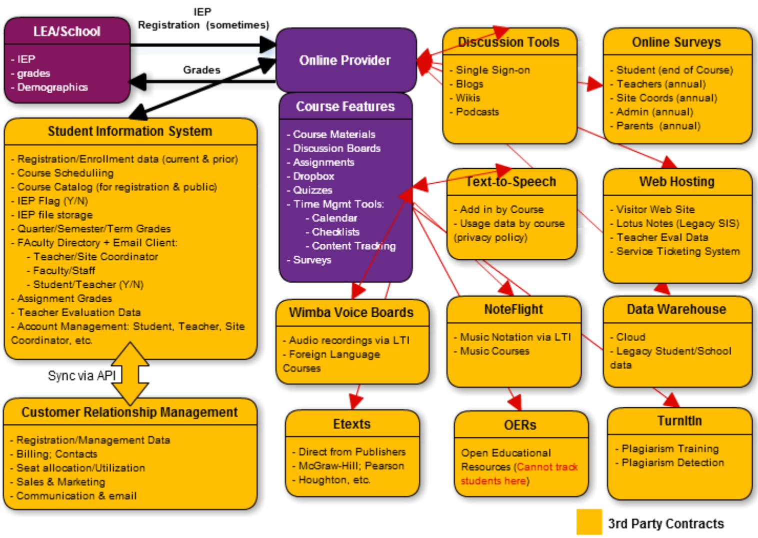

Figure 1. Schematic of secondary online learning system.

Researchers discovered that because of the data's importance and sensitivity, as well as the relatively small number of students on IEPs each year, the online school processed the IEP information manually outside of the system and no record of this was stored in the information system in a structured way. They did, however, store the course grades in a database in a structured form. The LMS provider provided a set of database files containing raw data on student usage of the platform.

Phase II was intended to be a prospective research study, involving NE1, NE2, and a new partner (a third-party provider of online ASR support integrated into NE1's classes delivered via NE2's LMS). Whereas Phase I was retrospective, Phase II started with some specific research questions and, based on those questions, the partners identified what data to collect and what technical changes to make to the platforms to support that data collection. Again, the first goal was to generate a USR including just a minimal set of variables—IEP status, usage of ASR in classes, and course grades. The ASR provider submitted samples of data they routinely collected and based on those samples researchers were able to draft a technical specification for the work that would need to be done by the online school, the LMS, and the ASR platforms to produce a USR for analysis (see Appendix B for a list of measures considered for inclusion in the Phase II USR).

Two collaborative and sequenced efforts were thus made to produce a USR to assess the impact of LMS usage generally (Phase I) and usage of a specific form of support (Phase II) on student outcomes. This approach to data analysis was anticipated to yield correlations that could help establish quantitative insight into the recruitment, enrollment, persistence, progress, and performance of students participating in this supplemental online learning program (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005). While major barriers ultimately prevented extraction of usable data, researchers concluded that detailing the results of this effort and the barriers encountered would benefit future inquiries and point to strategies for making these and similar data usable.

The sections that follow highlight the components of each of the Phase I and Phase II research efforts, the evidence basis for the research approach, and a detailed analysis of the barriers encountered.

PHASE I DETAIL: RETROSPECTIVE UNIFICATION OF STUDENT DATA

The intent of the initial systems review was to compile and analyze quantiative data collected by both the online school and the LMS on the recruitment, enrollment, retention, progress, and performance of SWD and to contextualize these data with descriptive information from interviews with staff. As a first step, a diagram summarizing the primary information systems where student and other data are stored was compiled (Figure 1). Following that, researchers set out to extract a minimal USR from historical data. Included in this plan were student data known from the interviews to be available. Specifically, an attempt was made to compile a USR using the following types of data elements: (a) demographic: student ID, IEP status (Yes/No); (b) usage: frequency of login, time spent on platform, optional features used, pages visited, and (c) learning outcomes: assignment scores, end-of-course grades, course completion (Yes/No).

Phase I Results

As had become clear from prior COLSD research and that of others, assessing the impact of digital curriculum content and digital delivery systems required attending to the three primary components of any online learning system: the learner, the system design, and the context of its implementation (Hamilton, Halverson, Jackson, Mandinach, Supovitz, Wayman, Pickens, Martin, & Steele, 2009; Miller, Soh, Samal, Kupzyk, & Nugent, 2015). By triangulating information about the student, his or her use of the online system, and any associated academic achievement outcomes, researchers hoped to identify patterns and relationships that could lead to more focused efficacy studies. This would enable the disaggregation of different student subgroups (in this instance, SWD and their peers) and would provide not just evaluative information on the system's current efficacy but formative information as well that would inform strategies to increase its efficacy.

Phase I revealed that, given how the system was configured, the data sought could not be readily collected and integrated into a unified record for analysis even though these data were being used operationally in the system either by machines or by staff and even though the school and the developer provided a large amount of raw historical data. A number of barriers were identified.

Barrier 1.1: Key data not reliably structured

Demographic data (such as a student's IEP status, gender, and age) were used by staff to support individual students but were not all recorded reliably in a form that could be extracted readily. From an operational standpoint, for example, important information about students includes (a) do they have an IEP, and (b) if yes, what are the recommended accommodations for that individual? Interview findings indicated that when an IEP is sent to the online school, it typically describes the necessary accommodations for a student. Usual protocol directs that a contact person within the school ensures that the IEP requirements are forwarded on to the student's online teacher(s), but since the school had no need for this information after the semester ended, they did not record it in the formal online student record. Therefore, the IEP information was not stored anywhere in the student information system. They did keep informal tallies of which classes students with IEPs enrolled in, as well as for other purposes.

Consequently, while the school was able to provide percentages of students with IEPs who were enrolled by simply counting the number of entries in the informal class list, no IEP flag could be reliably associated with each student in the data record for further analysis. This is an example of a situation where key demographic data were dissociated from the student usage and performance data (Figure 2). As a result, an analysis of the persistence, progress, or performance of SWD beyond enrollment counts was not feasible within the parameters of this study. Further, event information such as course drop-out/completion rates for SWD were only available via manual comparison of drop-out/completion and ad hoc IEP lists. This meant that relevant data (IEP status) recorded for one purpose (supporting accommodations for SWD) was not usable for analyzing patterns of student registration, enrollment, progress, completion, and/or performance since the design of the tracking system did not anticipate multiple or comparative use cases.

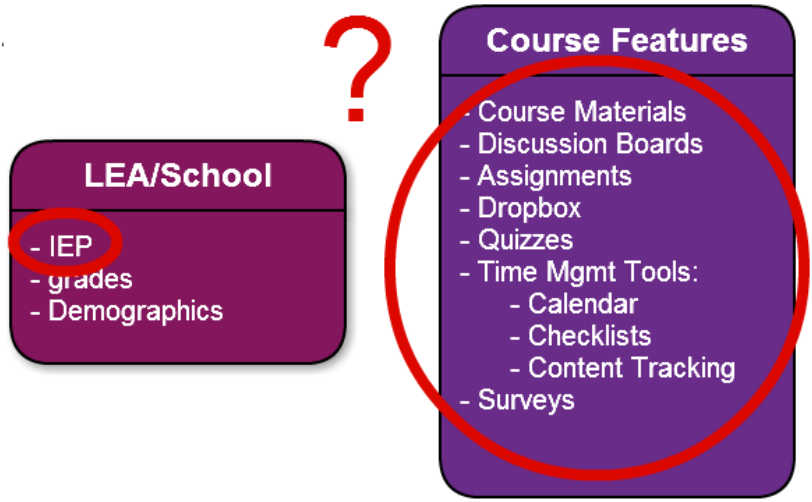

Figure 2. The disconnect between demographic data and online system usage information

Barrier 1.2: Data collected in structured formats was not interpretable.

While historical data were available for review, typical reports generated by the school focused on operational and instructional procedures not suitable for research on individual student activities. In most cases, the data sets acquired through the provided reporting functions represented only a fraction of the data generated by a student in an online course and were not sufficiently granular for establishing relationships that could support research or teacher decision-making on progress, performance, usage, needed supports, and other important questions about individual students.

Upon request, some of these more granular data were provided by the LMS partner for analysis as an extraction of raw data from their database. The database is complex, with student data distributed across many tables of information that all reference one another. To be usable for research associated with individual student activities, the database structure would have to be reconstructed from its parts. Once reconstructed, specific data would have to be extracted and flattened out into a two-dimensional array like a spreadsheet for analysis. During this process the data tables were revealed to have cryptic names like "CLASS_ACCESSES", and data fields within tables evidenced names like "OrgUnitId."

Under these circumstances it is not generally possible to make sense of large data sets in the absence of a data dictionary that explains what each field and each table represent. Researchers were provided with a data dictionary for some of the data sets, and from that were able to determine that there did not appear to be much in the way of useful data regarding student activity in this particular part of the system. Additional analysis efforts would have been expensive and labor intensive for both the school and the LMS vendor to provide, and given the quality of the data it was decided not to pursue it further in this project. Consequently, researchers were unable to accurately interpret student activity data for which clearly associated definitions (i.e., a "data dictionary") were not available. As a result, even though data are collected and stored they may be unsuitable for research purposes without significant additional investment in data extraction and preparation in close collaboration between brick-and-mortar schools, online schools, LMS providers, and researchers.

Barrier 1.3: Some data are proprietary

Online schools and LMS providers invest time and money in creating and refining their online technology platforms—platform design is part of their valuable intellectual property (IP) that they sometimes need to protect in order to preserve their ability to continue operating in a competitive environment. In some cases, sharing information, such as a data dictionary for their core database system, creates a risk of exposing their core IP, which, in turn, may produce a risk of undermining their sustainable business. Although the online school and the LMS developer were very open and collaborative in this project, there were elements they were not comfortable sharing. Consequently, just because data are collected and stored in a structured system in a form that might be usable for analysis does not mean they can be shared with others without substantial cost and/or risk to one or more stakeholders.

Barrier 1.4: Data may be expensive to extract with unknown research value.

Some student progress data presented to administrators and teachers via online "dashboards" might be unusable for research purposes. For example, administrators in the online school had access to student activity data (information on when students logged into a course, for example) but these data were only available in a form that was not immediately extractable for research. For example, login information for a single student or a single class may be displayed, but if there is no option to download or extract these data in bulk, manual collation is labor intensive, is beyond the resources available for this project, and may be prone to human error. Given current and common configurations, a manual data extraction process would have to be repeated for every student or every course, depending on what options are provided through the interface. In this case it can be seen that even though data are collected and stored in a structured system in a format that might be usable for research, and even though they are being shared with teachers and administrators for instructional purposes, that still does not mean they can be made available to others for different purposes, such as research, without substantial effort and cost.

While each of the enumerated challenges can be prohibitive individually, collectively they can be insurmountable within the parameters of many research projects unless these issues are considered and planned for at the outset.

The Impact of the Phase I Barriers

The barriers discussed above interacted in complex ways and presented both technical and operational challenges. An overarching principle that emerged from Phase 1 (the first attempt to develop a USR from historical data) is that current online learning systems are not necessarily designed to support this kind of research on student progress, persistence, and performance—whether they actually contain potentially usable data or not. Unless data tracking systems are designed to accommodate interoperable student data comparisons it is not feasible to assume that existing data sets can be used to gain any true measure of educational efficacy.

PHASE II: PROSPECTIVE ANALYSIS OF STUDENT LEARNING SUPPORTS

In light of the barriers encountered in Phase I, Phase II sought to identify the minimal set of technical changes that would be required to compile usable research data on the persistence, progress, performance, and malleable factors for SWD in an online setting. In this Phase, a fourth collaborator was added—a third-party provider of text-to-speech functionality, referred to as audio-supported reading or ASR. The ASR module connects to NE2's LMS platform and is used in some of NE1's online courses. ASR use was chosen to be monitored because many SWD have challenges with reading text-based media, online environments are often text-heavy, and text-to-speech is frequently an effective accommodation for SWD who struggle in reading (Izzo, Yurick, & McArrell, 2009; Meyer & Bouck, 2014). In Phase II, researchers sought to compile similar data as in the previous effort but specifically focused on students' use of ASR functionality in coursework.

From the full list of measures considered for this phase (Appendix B), the minimal set of measures in each category sought for the initial analysis are as follows:

- Demographic data
    - Unique Student Identifier
    - IEP Flag (Yes/No variable indicating if the student has an IEP)
    - Age, grade level, gender, ESS/ELL, school zip code
- Usage data: Text to speech
    - Course ID, Page ID
    - Student action (start audio, stop audio, pause audio)
    - Selected text (or “all”)
    - Time start and end for playing audio
- Student performance data
    - Assignment scores
    - Final grades
    - Participation scores (if available)

In Phase II the minimum goal was to collect data in each of the three categories (demographic, usage, and achievement) as a proof of concept for an analysis relating student usage of this support by SWD and their peers in an online setting to any associated academic outcomes. Potential applications of this type of analysis include informing teachers about student use of supports, performance, and work completion to guide instruction; and providing feedback on or knowledge of usage to inform students and help them to become more self-regulated learners (Steiner et al., 2015). COLSD researchers and their collaborators made promising progress on identifying a set of technical requirements supporting production of a USR. Through the process of working to implement this specification, researchers identified a number of new data-related barriers that need to be overcome to carry out this kind of research. These barriers included those described as follows.

Barrier 2.1: Key features used but not tracked.

Students may use features such as ASR within online courses, but no student-level data on this use were recorded (e.g., how much text was read, which text was selected for read-aloud). Operationally, ASR support is provided at the course level and the third-party ASR provider doesn’t need to store such data to provide the service nor to identify ASR use at an individual student level. Consequently, the existence of learning supports in an online environment does not imply that data regarding student usage of those supports are being recorded for future analysis.

Upon investigation of the data flow, it was determined that a unique student identifier (generally a coded number) would have to be passed through each part of the system to make it possible to unify the student data collected in each part for analysis. Passing such an identifier from the school through the LMS to the ASR module (a necessary requirement for matching student to ASR use), however, was found to require considerable technical work on the core LMS platform. This would have required an investment of time from senior LMS technical staff who were engaged with higher priority projects, and the work could have created a significant operational risk to the core platform. The LMS partner considered these costs and risks too substantial to justify adding the necessary functionality within the parameters of this project.

Barrier 2.2: Limited ASR access.

It was further discovered that ASR functionality was only available in limited areas of the school's courses, due at least in part to the way third-party functionality (e.g., within wikis, discussion boards, and ASR support) integrates into the core LMS. The ASR was made available only to read primary texts in the coursework and was not available to use in other areas such as wikis and discussion boards where students communicated with teachers and each other and where it might have supported writing as well as reading—despite the fact that the wikis and discussion board activities were perceived as specifically relevant to the school's cohort-based instructional model which was predicated on a critical mass of students interested in the same topic all learning together. Assignments and activities were primarily completed as an online group with teachers trained to facilitate text-based peer-to-peer interactions. The limited ASR availability severely limited the availability of ASR usage data.

Barrier 2.3: Limitations imposed by privacy concerns.

When the online school expressed interest in collecting data from students more systematically to better identify factors associated with the achievement of SWD, there was resistance from school superintendents whose districts contracted with the online school. Concerns and uncertainties related to student data privacy and compliance with federal and state data privacy laws were raised. Researchers believe that the challenge of generating a USR for analysis and efficacy investigations is a critical prerequisite for conducting ecologically valid research on the recruitment, enrollment, persistence, progress, and performance of all students in real-world, scaled online environments. In the majority of circumstances, research initiated on behalf of the student's "home" school is an allowable use of otherwise private information (34 CFR 99.31(a)(6)). In the case of an online school offering supplemental courses to many school districts nationwide, obtaining multiple permissions and agreements proved unworkable within the parameters of this research project.

DISCUSSION

Neither of the two phases yielded COLSD researchers usable data as hoped for, yet this inquiry provided significant insight into the practical challenges related to data identification, acquisition, and analysis that are faced by stakeholders seeking to assess the impact of online learning environments on student outcomes. In particular, these efforts revealed hidden complexities related to the management and use of student data and the fact that these complexities may not be widely recognized by students, parents, instructors, policy makers, researchers, and even online providers themselves.

Lessons Learned

Much of the data generated by K–12 online learning systems to date may not be configured, coded, or defined in a manner that supports research initiatives investigating individual student outcomes. It is possible to deliver most online services and supplemental supports (e.g., ASR) without recording any distinguishing information about the students (e.g., gender, age, ability) who use them. In fact, in many cases the provider of a particular service (like ASR) may not have any information about an individual student who is using the service at any given time. Without a student-level identifier that can be attached to each piece of a student's data allowing the data elements to be unified, data are virtually useless for the purpose of investigating learning activity, learning outcomes, or malleable factors, including differential behaviors and outcomes for different populations such as students with and without disabilities. To be clear, the problem is not simply that it is expensive or difficult to pull data together for analysis, but that without some way to associate a student-level identifier to individual data points it is *impossible* to conduct a post hoc analysis of tool usage by students. Some of the technical requirements to ameliorate this issue seem relatively minor, and the benefits could be substantial—rendering a great deal of operational data being generated by online providers much more useful for research purposes. Therefore, it seems a concerted effort should be organized to address it as soon as possible.

A review of the barriers and challenges encountered during this research effort also revealed that valuable and important data are being orphaned by the complex interaction of technical, legal, policy, and economic issues that arise between organizations. For example, if a school is the legal owner of a student's activity data that an online developer collects but the online developer does not provide a means for the school to extract those data in bulk then those data become unavailable to use for comparison purposes. Under current practices the LMS provider may not have the right to extract the data or provide them to a researcher for analysis, and the school does not have the means to extract the data for themselves or to provide them to a researcher. To enable viable research that could benefit all stakeholders, this capability must be pro-actively planned for and cooperatively built into the system. Benefits of this approach need to be made clear to LMS providers to justify the investment in the development of accessible and functional data sharing capabilities enabling evaluation and ongoing research.

Implications for the field

Given the distributed nature of many of the challenges identified in this research project, collaboration is essential. No single organization can resolve issues related to student data aggregation. At the very least, online schools must interact with their brick-and-mortar school counterparts and/or researchers from other organizations. In circumstances like those encountered in these inquiries, the systems involve many different providers each with their own platforms, technologies, and information systems, none of which have been designed to share student-level data. The field as a whole must develop sustainable models of collaboration that accommodate the economic, technological, legal, and other constraints and needs of the diverse participating organizations be they commercial, educational, academic, non-profit, governmental, or other.

Online learning platforms and online courses must be designed up front to support research. It is clear that there is no easy retrofit when it comes to using existing online data for learning analytics and research. Online platforms are generating huge volumes of data, but most of it is not only going unused—much of it, in its present state, is likely unusable for research purposes, which hinders its potential for assisting all stakeholders to support and improve online education for all students. This is not the sole responsibility of the LMS providers. Incentives, policies, and other supports must be put into place to enable them to take this issue seriously as a priority. When a student (including one with disabilities) moves online, there is no way to track persistence, performance, and progress or to identify malleable success factors. This is a serious problem. It would be beneficial to all learners to make these environments more research-friendly, but for SWD in particular it seems quite urgent.

Learning data interoperability standards are desperately needed in education (IMS Global, n.d.-a; Jakimoski, 2016; Maylahn, n.d.). Learning Tools Interoperability (LTI) and other similar standards already exist for the technical integration of learning systems (IMS Global, n.d.-b). These need to be further enhanced to support data interoperability and data quality, including provisions for the requirements of research. For example, as described previously, online platforms can provide a wide range of services without recording student-level data and without attaching a unique ID that can be used to unify the data for later analysis. Technical support for coordinating a unique student ID as well as guidelines for providers on best practices related to what data to store and what additional information to document, such as data dictionaries and naming conventions for database fields to make them more interpretable, should be added to the framework. IMS Global's Caliper framework (IMS Global, n.d.-a) is one example of a promising approach. Work on developing and disseminating this kind of framework should be supported by the field at large since this is a matter of shared concern with substantial benefits for all stakeholders.

Legal guidelines and standard data-sharing agreements regarding privacy, data ownership, and usage need to be more clear and more readily understandable. The Creative Commons Share Alike (CCSA) licenses, for example, provide a model for this kind of collaborative resource (see https://creativecommons.org/share-your-work/). CCSA licenses are standard licenses that were developed centrally and are made freely available to anyone who wants to use them. This approach dramatically reduces the overall cost of solving this problem compared to having every provider create their own one-off licenses—thereby lowering the barriers to entry and expanding participation. It provides a common framework and shared understanding that facilitates communication and decision making by the many providers and consumers of Creative Commons materials. A USR that allows for the association of demographic, usage, and achievement data with an individual student is a necessary requirement for realizing the full potential of networked learning environments. It can facilitate monitoring student progress, adapting instruction for diverse learners, conducting research on what is working more or less well for which students and under what conditions, testing design assumptions, and identifying ways to continuously improve the system. These benefits would be important for all learners, but especially those at the margins (such as SWD) who often fare least well and require the most adaptation and support to learn successfully. A centralized effort, analogous to the Creative Commons, to create and maintain the technical specifications, easy to understand legal and technical guidelines for each participating organization (e.g., brick and mortar schools, districts, online schools, online platform providers, third party tool providers, researchers), standardized legal agreements, model memoranda of understanding for each participant, and other materials necessary to produce USRs for research, could have a very profound positive impact on the pace, scope, quality, and cost of research and development in online education.

CONCLUSION

Triangulation is a fundamental orienting principle of surveys and navigation. It provides the location of an unknown point by creating intersecting lines from three additional, known points. The three major categories of existing student data sets common to most online learning environments—demographics, system usage, and achievement—offer the potential to triangulate these data, and, in sufficient quantity, to yield correlations that point to factors associated with greater than or less than expected academic achievement. These correlations, can, in turn, help to narrow the focus of subsequent efficacy studies. Knowing what works for which types of students under what circumstances is a core consideration of any instructional intervention, and this information could help curriculum designers and developers, school-based decision makers, parents, and students alike.

This research initiative from COLSD is felt to be a fairly representative depiction of the existing complexities—technological, policy-based, and legal—that can be encountered when attempting to combine student data from the three categories referenced above to gain a clearer picture of what is working and what is not. This challenge should be of particular concern for those crafting, implementing, and accounting for education services (including special education) for elementary and secondary SWD. For most struggling students engaged in full-time virtual schooling, direct, face-to-face monitoring of the type, duration, extent, and impact of support services is simply not available. Consequently, access to the data that includes these factors may not only be preferred but essential for both accountability and instructional purposes. In blended settings, where students may spend 40% to 60% of their curricular interactions online, similar access to meaningful data is critical. For students taking more limited supplemental online coursework, these data can be combined with direct observation and the face-to-face progress monitoring, observation, and communication afforded by the traditional approach to support service delivery that occurs in brick-and-mortar settings.

None of the challenges researchers encountered were felt to be insurmountable, yet each, in turn, was significant. In addition, each of the technological, policy-based, and legal issues requires the attention and expertise of a range of stakeholders: developers of digital curriculum and delivery systems, educators, technology standards experts, policy makers, researchers, and others. This indicates that an optimum approach to rectifying the current data discontinuity will require some consensus building among and across all of these groups.

ACKNOWLEDGEMENT

The contents of this paper were developed under a grant from the US Department of Education [#H327U110011]. However, the content does not necessarily represent the policy of the US Department of Education, and you should not assume endorsement by the Federal Government. Project Officer, Celia Rosenquist.

References

Baker, R. S. J. D. (2010) Data Mining for Education. In McGaw, B., Peterson, P., Baker, E. (Eds.) *International Encyclopedia of Education (3rd edition)*, vol. 7, pp. 112-118. Oxford, UK: Elsevier.

Barbour, M. K. (2013). The landscape of K–12 online learning: Examining what is known. *Handbook of Distance Education, 3*, 574-593.

Basham, J., Smith, S., Greer, D., & Marino, M. (2013). The scaled arrival of K–12 online education: Emerging realities and implications for the future of education. *Journal of Education, 193*(2), 51-60.

Basham, J. D., Stahl, S., Ortiz, K., Rice, M. F., & Smith, S. (2015). Equity matters: Digital & online learning for students with disabilities. Retrieved from Center on Online Learning and Students with Disabilities website: http://centerononlinelearning.org/wp-content/uploads/2015_COLSD_Annual-Publication_FULL.pdf

Bienkowski, M., Feng, M., & Means, B. (2012). Enhancing teaching and learning through educational data mining and learning analytics: An issue brief. *U.S. Department of Education, Office of Educational Technology*, 1-57. Retrieved from https://tech.ed.gov/wp-content/uploads/2014/03/edm-la-brief.pdf

Burdette, P., Franklin, T. O., East, T., & Mellard, D. F. (2015). I*ssues with Student Response Data from the Online Environment: State Education Agency Forum Proceedings Series.* (Report No. 4). Lawrence, KS: Center on Online Instruction and Students with Disabilities, University of Kansas.

Burdette, P. J., Greer, D. L., & Woods, K. L. (2013). K–12 online learning and students with disabilities: Perspectives from state special education directors. *Journal of Asynchronous Learning Networks, 17*(3), 65-72.

Charmaz, K. (2006) *Constructing grounded theory: A practical guide through qualitative analysis.* London, UK: Sage.

Cohen, L. M., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). New York, NY: Routledge.

Connell, M. W. & Johnston, S.C. (2015). *Descriptive study of an online educational technology provider operating in the K–12 field.* Manuscript in preparation.

Davies, J. & Graff, M. (2005). Performance in e-learning: Online participation and student grades. *British Journal of Educational Technology, 36*(4), 657-663.

Gemin, B., Pape L., Vashaw, L., & Watson, J. (2015). Keeping pace with K–12 digital learning: An annual review of policy and practice, 2015. *Evergreen Education Group.* Retrieved from http://www.kpk12.com/wp-content/uploads/Evergreen_KeepingPace_2015.pdf

Glaser, B. G. & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine Pub. Co.

Hamilton, L., Halverson, R., Jackson, S. S., Mandinach, E., Supovitz, J. A., Wayman, J. C., Pickens, C., Martin, E. S., & Steele, J. L. (2009). Using student achievement data to support instructional decision making (NCEE 2009-4067). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://ies.ed.gov/ncee/wwc/publications/practiceguides/

Harvey, D., Greer, D., Basham, J., & Hu, B. (2014). From the student perspective: Experiences of middle and high school students in online learning. *American Journal of Distance Education, 28*(1), 14-26.

Hung, J.-L., Hsu, Y.-C., & Rice, K. (2012). Integrating data mining in program evaluation of K–12 online education. *Educational Technology & Society, 15*(3), 27-41.

IMS Global Learning Consortium (n.d.-a). *Caliper analytics*. Retrieved from https://www.imsglobal.org/activity/caliperram

IMS Global Learning Consortium (n.d.-b). *Learning tools interoperability.* Retrieved from http://www.imsglobal.org/activity/learning-tools-interoperability

Izzo, M.V., Yurick, A., & McArrell, B. (2009). Supported eText: Effects of text-to-speech on access and achievement for high school students with disabilities. *Journal of Special Education Technology, 24*(3), 9-20.

Jakimoski, K. (2016). Challenges of interoperability and integration in education information systems. *International Journal of Database and Theory and Application 9*(2), 33-46.

Johnston, S. C. & Connell, M. W. (2015a). *Challenges at the intersection of a non-profit virtual school and a for-profit online platform provider working together in the K–12 field*. Manuscript in preparation.

Johnston, S. C. & Connell, M. W. (2015b). *K–12 students with disabilities in online supplemental courses.* Manuscript in preparation.

Kim, K., Schiller, E., Meinders, D., Nadkarni, S., Bull, B., Crain, D., & Thacker, C. (2015). *Summary of state policy on online learning.* Rockville, MD: IDEA Data Center.

Macfadyen, L. P. & Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers & Education, 54*, 588-599.

Markauskaite, L. (2011). Digital knowledge and digital research: What does eResearch offer education and social policy? In L. Markauskaite, P. Freebody, & J. Irwin (Eds.) *Methodological choice and design: Scholarship, policy, and practice in social and educational research.* London, England: Springer.

Martinez, M. (2002, May 7). What is personalized learning? *Learning Solutions Magazine*. Retrieved from http://www.learningsolutionsmag.com

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. Los Angeles, CA: Sage.

Maylahn, P. (n.d.). Eliminating ed tech havoc: Why open standards matter. Retrieved from Consortium for School Networking website: http://cosn.org/sites/default/files/pdf/CoSN_EdTechHavocReport_0.pdf

Meyer, N. K. & Bouck, E. C. (2014). The impact of text-to-speech on expository reading for adolescents with LD. *Journal of Special Education Technology, 29*(1), 21-33.

Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice.* Wakefield, MA: CAST Professional Publishing.

Miller, L. D., Soh, L. K., Samal, A., Kupzyk, K., & Nugent, G. (2015). A comparison of educational statistics and data mining approaches to identify characteristics that impact online learning. *Journal of Educational Data Mining, 7*(3), 117-150.

Molnar, A., Huerta, L., Rice, J. K., Shafer, S. R., Barbour, M. K., Miron, G., & Horvitz, B. (2014). Virtual schools in the U.S. 2014: Politics, performance, policy, and research evidence. Retrieved from National Education Policy Center website: http://nepc.colorado.edu/files/virtual-2014-all-final.pdf

National Forum on Education Statistics. (2015). *Forum guide to elementary/secondary virtual education data.* (NFES 2016-095). U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Reshef, D. N., Reshef, Y. A., Finucane, H. K., Grossman, S. R., McVean, G., Turnbaugh, P. J., & Sabeti, P. C. (2011). Detecting novel associations in large data sets. *Science, 334*(6062), 1518-1524.

Romero, C. & Ventura, S. (2010). Educational data mining: a review of the state of the art. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 40*(6), 601-618.

Rose, T. (2016). *The end of average: How to succeed in a world that values sameness.* London, UK: Penguin UK.

Steiner, E. D., Hamilton, L. S., Peet, E., & Pane, J. F. (2015). Continued progress: Promising evidence on personalized learning. Retrieved from Rand Corporation website: http://www.rand.org/pubs/research_reports/RR1365.html

Tanenbaum, C., Le Floch, K., & Boyle, A. (2013). Are personalized learning environments the next wave of K–12 education reform? Retrieved from American Institutes for Research website: http://www.air.org/sites/default/files/AIR_Personalized_Learning_Issue_Paper_2013.pdf

Thompson, B., Diamond, K. E., McWilliam, R., Snyder, P., & Snyder, S. W. (2005). Evaluating the quality of evidence from correlational research for evidence-based practice. *Exceptional Children, 71*, 181–194.

U.S. Department of Education, Office of Educational Technology. (2013). *Expanding evidence approaches for learning in a digital world.* Retrieved from http://tech.ed.gov/files/2013/02/Expanding-Evidence-Approaches.pdf

Zorrilla, M., García, D., & Álvarez, E. (2010). A decision support system to improve e-learning environments. In *Proceedings of the 2010 EDBT/ICDT Workshops* (Article #11). Retrieved from http://www.icdt.tudortmund.de/proceedings/edbticdt2010proc/workshops/beweb/papers/edbt_2010_submission_558.pdf

APPENDIX A
DESIRED DATA ELEMENTS CONSIDERED FOR INCLUSION IN A UNIFIED STUDENT RECORD (USR) FOR PHASE I

(Note: This list excludes specific usage measures, such as login events and learning features utilized.)

- Student demographic information
  - Unique anonymous student ID number
  - Birthdate
  - Name and zip code of brick-and-mortar school they attend (if appropriate)
  - IEP status (yes or no)—If yes, disability category/type (choose from a list)
  - 504 plan (yes or no)
  - Grade level
  - Race/Ethnicity
  - Gender
  - Language status
- Gross usage of the online platform
  - Number of online courses the student has taken prior to current year
  - Number of online courses the student passed, failed, or dropped/withdrew from prior to current year
  - Number and names of online courses student was enrolled in during the previous academic year
  - Number and names of online courses students dropped/withdrew from during the previous academic year
- Student achievement
  - Individual online assignment grades during the previous academic year
  - Student's online course quiz scores during the previous academic year
  - Student's online final course grades for the previous academic year

APPENDIX B
MEASURES PROPOSED FOR CONSIDERATION IN PHASE II

- Student information (demographic and other)
  - Unique anonymous student ID number (issued by the online school)
  - Student age
  - Student grade level
  - Gender
  - Zip code of home or school (proxy for SES)
  - IEP/504 status (binary flag: Yes/No)
  - Other courses student is taking simultaneously with the online course(s)
  - Prior enrollment in online courses, if any
  - Race/Ethnicity
  - Free/reduced-price lunch status
  - Is English the primary language spoken at the student's home?
  - Does student participate in an ESL/ELL (English as a Second Language/English Language Learners) program at their school?
- Course information
  - Course name
  - Course category information: Level, content, credit recovery, AP, etc.
- Student achievement data
  - Assignment scores
  - End-of-term grades for the course of interest
  - Overall course grades for the course of interest
  - Participation grade if it exists
  - Grades from other courses taken with the online course provider
- Data dictionaries for all available data sets
- Content usage (LMS events)
  - Student ID (if different from unique anonymous student ID number)
  - Online content page ID
  - Online content page section ID (if available)
  - Page load time stamp
  - Page exit time stamp, if available, or next page load time stamp

APPENDIX B, *Continued*

- Learning activities (for each technology component of interest, such as ASR)
    - Student ID that matches the online course student ID
    - Course ID
    - Course category
    - Page ID/URL
    - Page section identifier (if available)
    - Event ID (events triggered when student takes an action)
    - Event data and definition (text selected, text entered, options chosen, etc.)
    - Event time stamp where applicable—start/stop (or start and duration)