You Can Lead a Horse to Water: Teacher Development and Use of Digital Library Resources

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ABSTRACT
This article presents findings from approximately 150 users who created instructional projects using educational digital library resources. One hundred of these users were teachers participating in professional development workshops on the topic of digital libraries. Our iterative approach to tool and workshop development and implementation was based on a framework that characterizes several input, output, and process variables affecting dissemination of such technologies in educational contexts. Data sources involved a mix of qualitative and quantitative methods, including electronic surveys, interviews, participant observations, and server log file and artifact analyses. These multiple and complementary levels of analyses reveal that despite teachers reporting great value in learning resources and educational digital libraries, significant and lasting impact on teaching practice remains difficult to obtain.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *User-centered design, Evaluation/methodology*; K.3.1 [**Computers and Education**]: Computer Uses in Education – *Computer-assisted instruction (CAI)*

General Terms
Human Factors, Design, Experimentation

Keywords
Educational Digital Libraries, Evaluation, Empirical Studies, Reuse

1. INTRODUCTION
Much effort has been expended on creating infrastructures, technologies, and standards for digital libraries of learning resources. Prominent examples include the U.S. National Science Digital Library (htttp://www.nsdl.org), the Australian Learning Federation (www.thelearningfederation.edu.au), the European Union's Ariadne Foundation (http://www.ariadne-eu.org/), and EduSource Canada (http://www.edusource.ca). Key objectives of these initiatives are to improve teacher and learner access to high-quality learning resources and to increase their use in order to improve education [26, 30].

In this article, we take a broader view by proposing a framework that incorporates inputs and process variables affecting these desired outcomes. In the evaluation literature, this is referred to as a 'program theory' [17, 28]. Inputs include factors such as audience characteristics. Outcomes include increased teacher and student use of learning resources from digital libraries. In particular, two key variables are examined in this framework. The first is a professional development program aimed at educators on the topic of using educational digital libraries. The second is a simple end-user authoring service, called the Instructional Architect (IA). The IA helps users, particularly teachers, discover, select, sequence, annotate, and reuse learning resources stored in digital libraries [8, 20]. With the IA, users can create personal collections of instructional activities, lectures, lesson plans, study aids, or any kind of instruction around digital library learning resources.

As we will describe, the Instructional Architect provides a useful context for teacher development programs in that its use makes it easy to engage teachers in design activities using learning resources. In addition, analyses of resulting instructional projects provide a level of detail about resource usage typically not available by simply analyzing web server and query logs.

To assess the viability of this framework, we designed a series of studies to test the assumptions that linked program, inputs, processes, and outputs. These studies involved 100 educators who participated in professional development workshops that focused on digital libraries and use of the IA. The studies used mixed methods, including electronic surveys, participant observations, interviews, and usage data (including server log file and artifact analyses). The usage data can be contrasted with the activities of approximately 50 'organic' users, that is users who used learning resources and the IA without the benefit of formal instruction.

These multiple and complementary levels of analyses contribute to our growing understanding of knowledge, attitudes, usage, and impacts of educational digital libraries with a variety of educators in a variety of educational contexts, e.g., [2-4, 14, 19, 22]. Our findings suggest, that despite teachers reporting great value in learning resources and educational digital libraries, significant and lasting impact on teaching practice remains difficult to obtain. While some use-limiting factors are beyond digital library developers' control (e.g., technology infrastructure in school settings), systematic empirical testing can improve usability and impact. Nonetheless, much education remains to be done to help teachers and learners effectively integrate such technologies.

The next section of this article outlines the framework, followed by a description of the Instructional Architect, the development workshop, and its curriculum. We then present findings from our studies, and conclude with suggestions for future work.

2. FRAMEWORK

The framework guiding our evaluation studies is illustrated in Figure 1. The evolution of this framework was partly based on a review of the literature in teacher instruction in and adoption of information technology. It also resulted from iterative testing and refinement (described below).

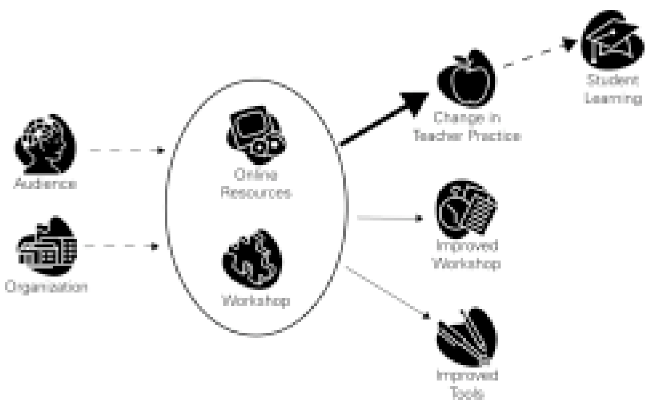

Figure 1. Evaluation framework

The left side of Figure 1 shows input variables that independently influence the effectiveness of the development and dissemination program. These include audience characteristics (technology comfort level, teaching orientation, grade level, and experience), and organizational factors (technology infrastructure and support, release time, availability of mentors) [1, 5, 13, 29].

The right side of Figure 1 represents intended outcomes, including a range of changes in teachers' practices (and, although not part of our current framework, leading to increased student use of learning resources and improved learning), and findings to iteratively help improve the design of the professional development curriculum, learning resources, digital library services, and the evaluation instruments themselves.

The middle of Figure 1 shows two variables of interest: 1) a digital library service (the IA) and 2) the professional development workshop curriculum model. These are described in the next sections.

The Instructional Architect: A Digital Library Service

The Instructional Architect (IA.usu.edu) is an end-user authoring service primarily designed to support use of resources in the National Science Digital Library (www.nsdl.org) in instructional contexts. The IA enables users (particularly teachers) to discover, select, sequence, annotate, and reuse online learning resources stored in any digital library into new instruction (e.g., lesson plans, study aids, homework). In this way, the IA is intended to increase the utility of online learning resources for the classroom educators [20].

The IA offers several major usage modes. First, with the '**My Resources'** tool, users can search for resources in the NSDL. Queries are sent to the NSDL search interface, which searches the union metadata repository, comprised of metadata records harvested via OAI-PMH from participating NSDL digital libraries [10]. The standard metadata set used by the NSDL repository consists of the Dublin Core set of 15 basic elements, the three extensions recommended by the Dublin Core Education Working Group [7], and NSDL specific fields (e.g., NSDLUniqueID, brandTitle) [16]. Item-level and collection level metadata records from participating libraries are normalized or cross-walked to the NSDL standard set. Users can also perform an advanced search in the IA, where they can narrow their search by restricting the Dublin Core FORMAT metadata field.

Metadata records for matching resources are displayed to users in an abbreviated form (title, author, brand, description, and date). After browsing these results and viewing resources, users can select desired resources for further use (see Figure 2). Users can also add any Web resource by entering its URL in the IA, and incorporating it into to their project. Of course, these Web resources do not have associated metadata records. Users can also organize their selected records in groups and folders.

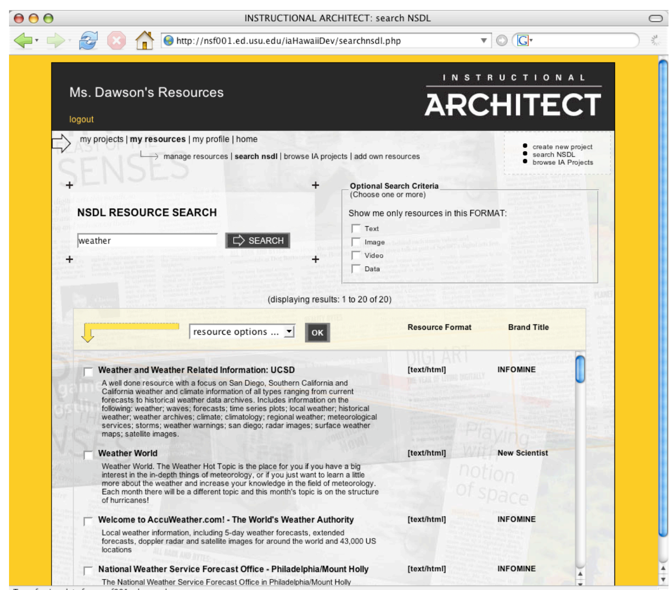

Figure 2. Searching for and selecting results

Second, with the '**My Projects'** tool, users can create web pages in which they sequence and annotate their selected resources in order to create instructional projects. Figure 3 shows an example screen shot from the '**My Projects**' work area.

Finally, users can '**Publish**' their projects and set permissions on who can view them, including user-only, their students, or anyone browsing the IA site.

An example of a user project can be seen in Figure 4. This user, a middle-school science teacher, was interested in developing

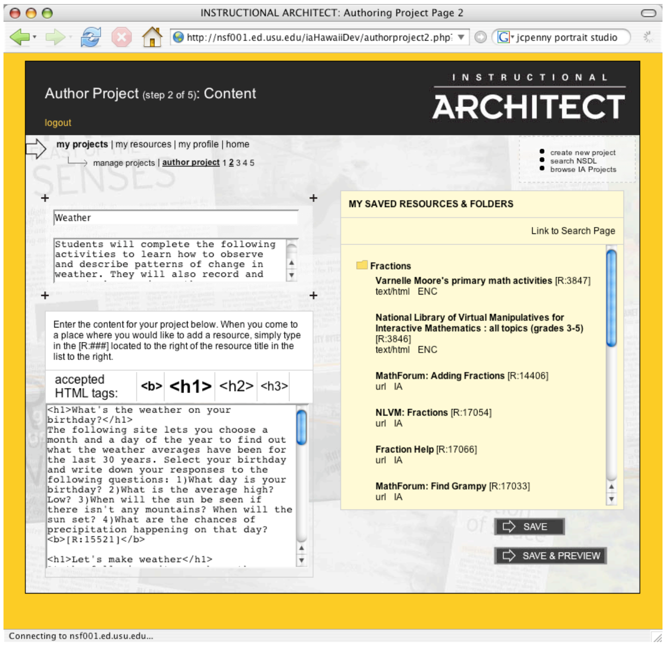

Figure 3. 'My projects' area

a unit on the topic of weather. She located an interactive weather simulator in the Digital Library for Earth System Education (DLESE) [11], an NSDL partner library. Using the IA, she added annotations and directions for her students as part of a homework activity.

The IA can be used as a portal site in the NSDL, where users can create accounts to store their personal list of resources and projects. IA functionality can also be implemented as a web service using SOAP (Simple Object Access Protocol). The interested digital library simply calls a remote method to pass the metadata of selected learning resources to the IA.

The IA is implemented on a Linux server running the Apache Web server, using a Postgres database. PHP (version 5.0) is used for dynamic content generation and communication between the Web server and database. The system has been developed following the open source software model, and the code base is freely available for download.

To accommodate persons with disabilities, the IA was implemented to be fully compliant with the Web Content Accessibility Guidelines [27], which is coordinated and established by the W3C Web Accessibility Initiative (WAI).

Teacher Professional Development

Much prior research has documented that effective teacher professional development programs are adaptable to target contexts, linked to relevant educational standards, hands-on, collaborative, and design-based [12, 18].

The workshop curriculum, designed to help participants integrate digital libraries resources in teaching, follows these guidelines. By using the IA, and its simple authoring and sharing capabilities, the workshop is design-oriented, hands-on, and collaborative. In addition, several aspects of the curriculum can be tailored to fit audience and institutional contexts.

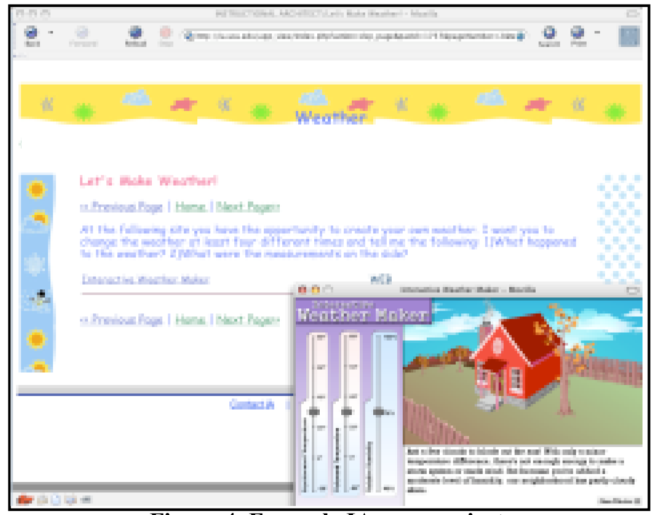

Figure 4. Example IA user project

Specifically, the workshop curriculum consists of the following components:

1. A motivating example. Depending on characteristics of the audience, a motivating and interesting learning resource from the NSDL (e.g., an interactive simulation of a frog dissection) is demonstrated to the participants. The example also shows the use of a learning resource in an instructional setting.
2. A description of the NSDL and its mission.
3. How to find learning resources in the NSDL, including keyword and searching, advanced searching, and browsing by categories. Depending on audience characteristics, amount of modeling is increased or reduced.
4. Participants identify relevant instructional objectives that align to specific core state and national standards for their subject area. Participants practice search techniques to locate resources related to their selected objectives.
5. A discussion on using learning resources in teaching. Participants are shown various methods and topics that could be used to present digital resources to their classrooms. Examples include labs, assignments, interactive group work, research, resource lists, and homework.
6. Instruction on and modeling use of the Instructional Architect, including creating instructional projects, finding learning resources, organizing and annotating resources, and publishing projects on the Web. Depending on audience characteristics, amount of modeling is increased or reduced.
7. Guided practice on creating individual projects with NSDL learning resources and using the IA.
8. Participants demonstrate their created projects.

A complete description of the curriculum is available at http://dlconnect.usu.edu/htm/download.htm.

3. METHODS

To assess and refine the framework, we conducted a series of five workshops with different groups of educators. We were interested in assessing the utility and impact of the workshop and digital library resources and tools by testing the assumptions that link the framework's inputs, processes, and outcomes. In particular, several research questions guided our work:

- What is the usability and utility of the learning resources and tools?
- What is the effectiveness and impacts of the professional development program on the knowledge and attitudes of different kinds of teachers?
- How are participants using various kinds of learning resources? What search strategies did they use? How did they organize learning resources into instructional projects?
- Are there differences between the workshops attendees and the non-workshop (organic) users?

Procedure

Over the past 1.5 years, the workshop has been implemented five times with different groups of educators. Each workshop was conducted in a computer lab where each participant sat at an Internet-connected computer. The instructor had a projector to demonstrate the software to participants. Each workshop also had several facilitators, who recorded their observations.

Workshop duration varied between 3 and 12 hours (see Table 1). Participants completed a pre-survey at the beginning of the workshop, and a post-survey at its conclusion. Some also participated in post-workshop focus group interviews.

Each workshop implementation was accompanied by evaluation, so that data collection could inform the next development cycle for the IA, instruments, the curriculum, and the evaluation instruments. In addition, methods focused on measuring input and output variables identified in the framework.

We used a mixed method approach [9], triangulating findings from pre- and post-workshop online surveys, participant observations, group and key informant interviews, and also analyses of web server logs and artifacts created by workshop participants. Data analyses consisted of item and factor analyses to establish the reliability and validity of the survey instrument, and statistical analysis and thematic coding to address the research questions.

The survey items included a number of Likert-scaled and open-ended items intended to collect demographic information and to measure teachers' prior knowledge and experience regarding digital libraries and learning resources, their attitudes towards their utility, the technology infrastructure in their schools, and their opinions on the usefulness of the workshop. The Likert-scale items had anchors from 0=very low to 4=very high (mean=2) and could not be left blank. The list of survey items is available at http://dlconnect.usu.edu/htm/download.htm.

Table 1: Participant demographics

Workshop	N	% female	Mean age	Tech use in school	Workshop time (hrs)
1. Pre-service teachers	34	n/a	n/a	n/a	3
2. Pre-service teachers	14	n/a	n/a	n/a	3
3. SLMS	13	92	44	3.4	12
4. In-Service science	17 (23)	47	38	2.7	6
5. In-service science and math	18	83	52	4.4	6

Participants

Table 1 shows participant demographics for the five workshop implementations. These involved pre-service (learning to become) teachers, school library media specialists (SLMS), and middle and high school science and mathematics teachers. Participants in the first three workshops were involved as part of coursework; participants in the last two were involved as part of regular school district level teacher development opportunities. There were 23 participants in workshop 4 but, due to server problems, valid surveys were only received from 17 people.

The table shows the gender composition and mean age for various participant groups. It also reports the mean for each group's self-reported level of technology use in the classroom on a scale of 1 to 5 (1=very low; 5=very high).

4. FINDINGS

Participant knowledge and attitudes

Across all workshops, participants varied in their understanding of what constituted learning resources and the NSDL. However, post survey results showed that all participants understood these concepts after the workshops (see Table 2).

Table 2. Pre- and post-workshop participant knowledge, attitudes, and experience (percentage)

Group	Pre-knowledge about learning resources	Post	Pre-knowledge about NSDL	Post
1	71	100	0	100
2	92	100	0	100
3	77	100	46	100
4	100	100	18	100
5	94	100	17	100

These data must be interpreted with care, as the wording used on the evaluation instruments changed considerably with each workshop iteration. For example, we initially used the term 'digital resource' but found that some participants interpreted this to mean 'digital camera.' This seemingly simple confusion highlights the importance of using language that is familiar to participants, and of explicitly defining terms used in the workshop curriculum. After trialing different terms, we settled on "online learning resources".

In general, in-service teacher participants reported having a moderate amount of experience teaching with learning resources. For example, a Likert item (with anchors from 0=very low to 4=very high) used to assess participant experience had means of 2.2 and 2.8 for participants in workshops 4 and 5, respectively.

Digital Library Service and Curriculum Utility

Table 3 shows means from Likert items designed to assess participants' attitudes towards the curriculum, learning resources, and technologies. In general, participants were very positive. Participants were enthusiastic about the value of the NSDL, the quality of the discovered learning resources, the value of the IA, and the value of the workshop. Participants also generally reported that they would recommend the IA to other teachers.

It is worth noting the overall lower means for participants in workshop 4. Although the curriculum and the overall workshop experience were very similar to workshop 5, these participants appeared less satisfied. Participants in workshop 4 also reported much less technology use in their schools in contrast to participants in workshop 5 (see Table 1). In addition, Internet access at home differed between these two groups, with four of 17 (24%) workshop 4 participants indicating no Internet access, while just one of 18 (6%) in workshop 5 indicating no Internet access. As such, it is possible that lower levels of technology infrastructure decreased the perceived value of digital libraries, resources, and services.

Table 3: Means for Likert items (with anchors from 0=very low to 4=very high)

Group	Value of NSDL	Quality of resources	Value of IA	Value of workshop	Recommend IA to other teachers
1	3.4	n/a	3.5	3.6	3.7
2	3.4	3.4	3.3	3.4	3.4
3	3.5	3.6	3.5	3.5	3.7
4	2.9	3.1	2.5	2.4	2.0
5	3.6	3.3	3.7	3.8	3.7

In post-workshop group interviews, the pre-service teachers (workshops 1 and 2) reported needing less modeling and group exercises, and reported that they could have begun to use the IA much earlier in the workshop than we had anticipated. In general, our observations suggested that participants in these workshops were younger and more comfortable with information technology and the Internet than their in-service counterparts. This finding underscores the importance of having adaptable workshop components to better match participant capabilities.

These early workshop participants also expressed the desire for incorporating non-digital library resources, such as Web URLs, into their projects. They also requested more graphics and text editing functions for the IA, such as bold and colored text, as these functions could help hold the attention of younger users in classroom environments. Both of these features were subsequently added. Thus, while teachers appeared to value accessing high-quality and vetted learning resources, they did not want to be limited to them.

Discovery and Use of Learning Resources

The instructional projects created by IA users offer a unique window into understanding how teachers intend to use digital library learning resources in instructional contexts. While analyses of server and query logs can reveal user search terms and resource downloads, IA projects show how users organize and annotate learning resources. In addition, because the IA is available as an Internet portal, data from workshop participants can be contrasted to usage activities from 'organic' users, that is users who did not benefit from formal instruction.

We can assume that these users did not have formal instruction because they created their accounts outside of the workshop periods. In particular, we included in our analysis users who created and used IA accounts during the period workshops were offered (January 1, 2003 to November 1, 2004), yet outside of the specific workshop days.

Table 4. Project, accounts, and resource usage for different participant groups

Group	Accounts (%)	Projects (%)	Mean # of projects	Mean # of resources per project
1	32 (22)	34 (18)	1.1	4.4
2	14 (9.5)	19 (10)	1.4	3.7
3	13 (9)	14 (8)	1.1	9.1
4	23 (16)	24 (13)	1.0	2.7
5	18 (12)	25 (14)	1.4	2.8
Organic	46 (31.5)	69 (37)	1.5	3.5
Total	**146**	**185**	**1.3**	**3.9**

Table 4 shows the number of accounts and projects created by participants in the workshops, as well as the organic users. Users created a mean of 1.3 projects (SD=.6), with 20% of the users creating two or more projects. They used a mean of 3.9 learning resources (SD=3.6) per project, with 37% of the users using four or more resources per project. Thus, despite their overall favorable impressions, the majority of users did not show a sustained use of the IA and learning resources. Perhaps not surprisingly, the most negative group (workshop 4) created the fewest amount of projects and used the fewest amount of learning resources. While organic users comprised our largest user base, their project profile is similar to the workshop participants (see Table 4).

Discovery strategies. An analysis of terms used to search the NSDL showed that the vast majority was comprised of just one keyword. The advanced search feature was almost never used. This simple use of discovery systems by teachers has been documented in the literature [21, 25].

Origin of resources. In response to user request, we added a feature to the IA whereby non-digital library resources (i.e., Web URLs) can be inserted in IA projects. The number and percentage of learning resources used in projects from the various libraries that are part of the NSDL, the Web, and other digital libraries are listed in Table 5. Overall, 407 (53%) NSDL resources were used in these projects compared to 305 (39%) Web resources.

Although Web resources comprised the plurality used, it is an overestimate. In our observations, we noted that often participants located a resource within a digital library (at a lower level of granularity than cataloged), and then copied and pasted that URL into their project. From a database point of view, although this resource was discovered within an NSDL digital library, it simply appears as a Web resource (without accompanying metadata).

We conducted a simple experiment to estimate this error. Ten percent of the Web resources were randomly selected and then manually checked to see if they originated from an NSDL partner digital library. Results show that just over 70% of these Web resources were 'most likely' from an NSDL partner library. As such, NSDL resources appear to be of high value to participants, yet often at a lower level of granularity than cataloged. The result of this experiment also highlights the important of triangulation multiple sources of data. Without participant observation, we would not have noticed that participants were copying-and-pasting URLs from digital libraries.

Table 5. Distribution of learning resources from partner NSDL digital libraries

Origin		Frequency	Percent
Web		305	39.4
NSDL	DLESE	96	12.4
	Math Forum	70	9.0
	ENC	63	8.1
	Internet Scout	37	4.8
	LON-CAPA	19	2.4
	ICON	15	1.9
	COMET	13	1.7
	Mathworld	12	1.6
	NASAEDmall	12	1.6
	Awesome Library	12	1.6
	Other NSDL partners	58	7.5
	Total	407	52.6
Other digital libraries		56	7.2
Missing		6	0.8
Total		**774**	**100**

It would be interesting to correlate the size of the various collections with frequency of use. The correlation value might suggest if it is the number of resources (high correlation) or their utility (low correlation) that affects participant selection of resources. Unfortunately, the NSDL does not readily provide statistics on the size of partner libraries.

Resource metadata. The advantage of an educational digital library is the rich metadata that it can provide. Table 6 shows the percent of NSDL resources described by various metadata fields.

Only 10% of the NSDL resources used in projects had both Dublin Core subject and audience metadata fields. Only 4.2% of the resources used had audience metadata, while 29% had subject metadata. It is unknown if this is representative of the NSDL collections. As such, it remains unclear how important such fields are in supporting resource discovery.

Table 6. Percent of NSDL resources with various metadata fields

Metadata field	# of NSDL resources with this element (%)
Format	258 (63)
Format: txt/html	186 (46)
Subject only	120 (29)
Both subject and audience	40 (10)
Audience only	18 (4.2)

In terms of resource format, 63% of the NSDL resource contained that metadata field. Of these, 72% of the resources were of format 'text/html' (or 46% overall). Again, it is unknown if this is representative of the NSDL collections. The high use of this format may also be due to participant comfort level, the workshop examples, or to the fact that the IA does not easily allow the manipulation of dynamic formats and data sets.

5. DISCUSSION

Despite teachers' self-reports on the value of learning resources, the NSDL, the IA, and their positive impacts on education, persistent use remains difficult to obtain. Only a small portion of workshop attendees and organic users created multiple and complex projects. We note that this is not an uncommon finding in the teacher professional development literature, whereby attendees report positive experiences yet show little change in their teaching practices. [6].

Some variables that influence educator use of online resources are beyond the control of digital library developers. For example, studies show that teachers are chronically busy [24], which means that developers must ensure that the cost adopting new technologies is low. Our findings suggest that these barriers may be reduced with younger teachers, who may be more fluent in Internet technologies. Not surprisingly, our findings also suggest that teachers with poor access to technology will remain slow or non-adopters. These contextual variables may influence the degree to which educators embrace sustained use of digital resources. However, the assumption that sustained, post-workshop use of digital resources can be assessed through analysis of IA user statistics may need further investigation. While we have some evidence from post-workshop interviews and observations, it is entirely possible that participants who benefited from the IA workshop, may also utilize other software programs to access digital learning resources.

Other variables can be immediately addressed. Iterative testing and refinement of software tools ensures that they better meet the needs of their intended audience [15, 23]. Group interviews help identify the language used by the target audience (which is often very different from the language of developers). However, it seems clear that much education must be done to help teachers fully understand the effective discovery and use of digital library resources in ways that impact their practice.

Our testing also revealed the importance of allowing users to incorporate non-digital library resources within instructional projects. While the issue of the quality of resources in digital libraries remains paramount, it seems clear that our users did not want to be restricted.

In group interviews, participants mentioned the importance of discovering grade-appropriate resources. Yet, as discussed above, few resources contained the audience metadata field. It is unclear if that situation will change, or if participants prefer to make their own judgment. Participants also mentioned the importance of discovering resources aligned to U.S. state and federal teaching standards. To date, few digital libraries have incorporated this kind of metadata as it is expensive to implement.

6. LIMITATIONS AND FUTURE WORK

This research has several limitations, including a) participant self-selection, b) the use of self-report survey data, c) the lack of follow-up, and d) limited sample size. In this section, we briefly address these problems.

First, participants in the workshop were either enrolled in classes or chose to engage in professional development opportunities. As such, it is difficult to know how comparable they would be to a randomly selected sample in terms of comfort with information technology, the Internet, and the use of learning resources in the classroom.

Second, some conclusions were based on self-report survey data, which may be subject to recall bias and hence under-reported or over-reported. In particular, due to the halo effect, participants possibly overstated the value of the workshop and digital library tools.

Third, little contact occurred with participants after the workshop. While our web server log files reported subsequent use of the IA, we don't know much about how IA projects and learning resources were subsequently used (if at all) in classrooms. In particular, we have no data regarding impact on the most important audience for educational digital libraries, namely students.

Finally, sample sizes are an issue on several fronts. Because the workshops have been conducted with different types of participants, the data cannot be pooled to obtain statistical power. Likewise, the measurement instruments have evolved over time, and the online design with item-pool means that dissimilar groups do not answer identical items.

In future work, we plan to address some of these problems. First, in ongoing work, we are conducting follow-up interviews with workshop participants to better understand subsequent use. This will include identifying barriers to classroom use, and providing onsite support. Providing more sustained instruction may help change teacher practices.

We are also conducting classroom observations to document teacher use of learning resources in learning activities. These studies will inform research designs for future studies investigating impact on students. Ideally, the latter will include some measure of impact on student learning.

Second, we are addressing issues of scalability by implementing an online version of the workshop curriculum. We hope that an asynchronous instructional program can increase dissemination by increasing the number of participants. It can also increase the range of participants by not requiring them to travel to workshop sites.

Finally, we are exploring a workshop model where a cadre of teachers is trained to become teacher trainers in their district. While this will also increase dissemination, we hope that it will also improve workshop impact since teacher trainers can also act as mentors. Indeed, anecdotal evidence suggests that this is already happening.

7. CONCLUSION

In this article, we presented findings from approximately 150 users who created instructional projects using educational digital library resources. One hundred of these users comprised teachers participating in professional development workshops. Our iterative approach to tool and workshop development and implementation was based on a framework that characterizes input and processes variables impacting dissemination in educational contexts.

Findings from these studies and the evaluation framework contribute to a growing empirical body of research on usage of digital library and resources in educational contexts. Our development, validation, and dissemination of workshop assessment instruments and interview protocols provide valuable resources for future research. The focus on testing the assumptions that link inputs, processes, and outcomes of a common program theory provides direction and insight on a critical and timely need in digital library research. Clearly, the assumptions that link outputs of digital libraries, service software, and professional development with desired outcomes of increased educator use of high-quality on-line digital resources need further analysis. In an era of accountability, exposing a theory and set of assumptions to testing increases the likelihood that we may eventually understand what it is that leads the horse to drink.

8. ACKNOWLEDGEMENTS

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