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Implementation Devices for Maintaining Record of Learning Data

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ABSTRACT

Educational standards often specify learning goals, which outline what a student should know at each academic level. Thus, assessment, which measures a learner's skills against learning objectives and goals, plays a central role in learning. However, data from the common forms of assessment are not adequate for answering questions such as: Why is the student not ready for fifth grade or for high-school Algebra II? In such cases, rather than relying on the usual assessment methods, a complete education audit may be required. Thus, the focus of the research presented in this paper is on devising mechanisms and systems to automate the collection of all forms of learning artifacts so as to support education audit for the individual learner. The paper proposes the use of record of learning as a means of establishing the competency and skills of leaners over time, and presents implementation devices for maintaining record of learning data to enable education audit.

Keywords: Learning artifacts, record of learning, competency and skills, assessment, temporal database management, work sampling system, education audit, individualized instruction, education plan

INTRODUCTION

Determining the knowledge and skills of a learner is a prelude to providing that learner with individualized instruction. Thus, assessment plays a central role in learning, especially in the compulsory phases of education, which involves students around ages 4 through 16. Formative assessment or "assessment for learning" provides input to the instructional process, while summative assessment usually records the learner's competencies and skills as grades or scores on exams. However, while assessment may be classified into two general categories, there is no general agreement among practitioners and researchers in the field of education on what constitutes formative assessment (Dunn and Mulvenon, 2009; Bennett, 2011). What is not debatable is the significance of formative assessment in learning, as indicated by the intensity of research and activities on assessment policy and practice (Andrade and Cizek, 2010; Clark, 2011; Gardner and Gardner, 2012). Furthermore, schools and educational agencies use summative assessments periodically to provide a measure of success of a program or a school. In the United States, the National Assessment of Educational Progress administers assessments of what students know and how they perform in various subject areas; results, which serve as a common metric for all States and selected urban regions, are reported periodically as national education report cards (The Nation's Report Card). Also, early education programs (National Association for the Education of Young Children, 2005; Sandall et al., 2000) recommend individualization of teaching based on ongoing assessments.

However, there are circumstances when the two main forms of assessment fall short to establish an education plan for a student; grades and other forms of assessment do not always reflect the level of knowledge and skills of the student. Across schools, and even within the same school, there is usually a wide range of abilities among students who have earned the same grade in a course. But, perhaps, the most serious circumstances concern students whose knowledge and skills lag considerably behind their respective assigned academic levels or those students who have successfully completed prerequisites for a course but lack the skills to succeed in subsequent target courses. It is also difficult to determine the skills and abilities of students in the compulsory education grade levels who change schools often. In such cases, rather than relying on the usual assessments, a complete education audit may become necessary.

This paper deals with mechanisms and systems to automate ongoing assessment and the collection of learning products. Even though research has shown that ongoing assessment does lead to better outcomes, their use is limited beyond the lower grade levels. Ongoing assessment is a tedious process that requires the commitment of teachers who have the skills necessary to perform the tasks. However, there is no clear evidence that teachers in the compulsory education phase have the skills to perform ongoing assessment properly. Indeed, the Office of Planning, Research, and Evaluation within the Administration for Children and Families, U.S. Department of Health and Human Services, commissioned a study to determine how early education teachers carry out ongoing assessment to effect individualized education plan and instruction. The report of the study (Atkins-Burnett et al., 2014) states that "ongoing assessment of children's progress is increasingly a priority in early childhood classrooms, yet teachers' use of these assessments has not been extensively researched" and calls for the development of a measuring tool that will gather relevant data consisting of document reviews, video-based observations, and teacher interviews. A companion report (Akers et al., 2014) provides a literature review of the most common approaches to ongoing assessment used in early childhood classrooms.

Providing education audit capability would require more learning data than is currently available through typical assessment processes. Also, performing ongoing assessment is a tedious process. Thus, there is the need to automate the ongoing assessment process. The focus of the research presented in this paper is on devising mechanisms and systems to automate the collection of all forms of learning artifact so as to support education audit for the individual learner. The paper proposes the use of record of learning as means of establishing the competency and skills of leaners over time, and presents implementation devices for maintaining record of learning data.

EDUCATION AUDIT

Research on *How People Learn* (Bransford et al., 2002) has shown how technology can contribute to the design of systems for implementing sophisticated classroom-based formative assessment practices and for supporting individualized instruction. However, for a student whose actual grade-level is a couple of years behind his assigned class, data from classroom formative assessments and large-scale assessments are not sufficient in answering such questions as: Is the student ready for fifth grade or for high-school Algebra II? The motivation for the research on the use of learning artifacts to assess learners' knowledge and skills is based on the supposition that tailoring instruction and learning for the highly mobile or low-performing student requires knowing his or her complete learning history, including not only assessments but also the performance artifacts and products produced by the student.

Thus, providing remediation would require more than just checking grades in classroom assessments or performance in a large-scale assessment. The learning history of the student must inform the remediation process. It should be possible to answer questions regarding students' learning at various levels of granularity. At the highest level, questions could be asked about a student's readiness for a grade level. But, typically, being ready for a grade level will involve meeting requirements for courses, and within courses milestones, and within milestones learning objectives. For the students who need remediation or specialized education plans, an education audit should be able to answer questions such as:

- Which learning objectives or milestones have not been met by a particular student?
- How much improvement has a student made over a period of time with respect to certain course objectives or milestones?
- Why is the student not ready for fifth grade or for high-school Algebra II?
- When did the student meet a particular learning objective or milestone?
- What did the student accomplish in week 12, fall of 2011 with respect to a learning objective?

An education audit is required to find answers to questions that will shed light on how a student arrived at his or her skill level.

RECORD OF LEARNING

The significance of using expanded record of learning to inform individualized instruction has long been recognized. As reported in the research on *Knowing What Students Know* (National Research Council, 2001), student performance should be described in more detail than formative and large-scale assessments. Quellmalz and Haertel (2000) assert that "traditional, on-demand tests still favor breadth of content coverage over depth of reasoning," and argue for “performance-based, technology-supported student assessment.” In this section, previous work on models and frameworks for maintaining record of learning are presented. It should be noted that some of the models presented do not allow for storage of the work products of the learner, but such models can be extended to include storage of the associated learning artifacts.

Performance Assessment Tasks

Performance assessment tasks, which call for students to create sample products or to demonstrate performance that can be rated, provide ways for students to show their proficiency in specific subject areas. The Performance Assessment Links in Science (PALS) project (Quellmalz et al., 2000) developed an online performance assessment resource library, which consists of standards-based performance assessment tasks for elementary, middle, and secondary grade levels. The tasks in the PALS collection, which come from various sources, including State Departments of Education, are indexed to various standards. Each task in the collection is well-defined to include: student directions and response forms, administration procedures, scoring rubrics, examples of student work, and technical quality data calculated from field testing. The following paragraph illustrates the use of performance assessment tasks relating to the National Science Education Standards; full descriptions of the tasks for the science standard can be found in the PALS guide (PALS Guide, 2015). Also, Figure 1 as an example, depicts a matrix of tasks and the related components, and the following list of five tasks gives the synopsis for each sample task shown in the figure:

- Task T1 (Acid and Base Testing 2 – Micro): Students design the procedures and then carry out an experiment to determine which of three solutions is acidic, basic, or neutral
- Task T2 (Acids and Bases -- Vinegar I): In the first part of Acids and Bases - Vinegar, entitled "Discovery," students will design and perform an experiment. Students will use a Universal Indicator Color Guide to measure the strength of acids and bases, as well as what happens when acids and bases are mixed together
- Task T3 (Acids and Bases -- Vinegar II): In the second part of Acids and Bases – Vinegar. titled "Recipe," students are guided through the experiment found in "Discovery"
- Task T4 (pH Acid Base Indicators): Student determine pH values of 4 for unknown solutions then demonstrate their understanding of the role of acid-base indicators as a function of pH
- Task T5 (Electrical Circuits and Switches): Students draw circuits and switches, explain how they work, then change their design for someone without hands to turn the switch on or off

	TASKS				
NSES Standards	T1	T2	T3	T4	T5
Develop descriptions, explanations, predictions, and models using evidence (8ASI1.4)	X	X	X		
Characteristic properties (8BPS1.1)	X				
Design and conduct a scientific investigation (8ASI1.2)		X		X	
Use appropriate tools and techniques to gather, analyze, and interpret data (8ASI1.3)		X	X		
Use mathematics in all aspects of scientific inquiry (8ASI1.8)		X	X		
Characteristic chemical reactions (8BPS1.2)		X	X		
Electrical circuits (8BPS3.4)					X
Design a solution or product (8EST1.2)					X

Figure 1: Matrix of Tasks and NSES Standards

The Performance Assessment Links in Math (PALM Guide, 2015), a resource bank of mathematics performance assessment tasks that is indexed via the National Council of Teachers of Mathematics (NCTM) standard, is also being developed for mathematics. We propose the use of standards-based performance assessment tasks as the main vehicle for maintaining students' record of learning, where learning artifacts data in science and mathematics will consist of students' work and response to PALS and PALM tasks.

Work Sampling System

Work Sampling System (WSS) is a performance assessment method in which the teacher assesses and documents the skills, knowledge, and behaviors of students in the early education stages using actual observed classroom experiences and activities and the work produced by the student. WSS is an ongoing assessment methodology; it consists of three complementary elements (Dichtelmiller et al., 2001): (a) developmental guidelines and checklists, (b) portfolios, and (c) summary reports. The teacher uses the guidelines and checklists to assess the performance of the child with respect to the criteria on provided rubrics. A student's portfolio consists of his work, which is collected as the class cohort goes through the curriculum. The last component is the teacher's report, which gives a summary of each child's performance in the classroom. There is much evidence from previous research (Fuchs and Fuchs, 2006; Connor et al., 2009; Ball and Gettinger, 2009) ~~has shown~~ that ongoing assessments do lead to better outcomes.

Phonological Awareness Literacy Screening (PALS)

Phonological Awareness Literacy Screening (PALS) (Invernizzi et al., 2004 - 2009) is an early literacy screening tool, which provides a comprehensive assessment of young children's knowledge of the important literacy fundamentals that are predictive of future reading success. As a practical matter, PALS is administered three times a year to assess and measure literacy components such as alphabetic recognition, blending, spelling/phonics, and oral reading in content. PALS also provides "Quick Checks" assessments (Quick Check Guidance Document), which are brief measures that allow students' progress to be monitored in between the PALS assessments. Research (Invernizzi et al., 2004) has shown PALS to be a valid screening tool that can be used reliably to identify children who would require additional assistance in early literacy development.

IMPLEMENTATION DEVICES FOR LEARNING ARTTIFACTS DATA MANAGEMENT

Capturing all forms of students' learning products and record of learning calls for technology-enhanced methods and systems. Also, providing education audit capability requires more learning data than available in current ongoing assessment processes. Thus, there is the need for an expansive record of learning that includes work products associated with standards-based performance tasks, oral and written response to in-class questions, and the interaction with peers in collaboration projects. Furthermore, in order to support education auditing, a core requirement is the ability to model time and to manage learning artifacts data across time dimension. This approach uniquely contributes such features and functionalities. Presented in this section are proposed implementation devices and technologies to facilitate learning artifact data management for education audit.

Learning Record Store

A Learning Record Store (LRS) is a system that stores learning information or statements of experience in the form “I did this” or “Actor verb object.” The main function of an LRS is to validate and store incoming statements in accordance with the Experience API (xAPI) (xAPI 2013) and to retrieve the data when queried by a Learning Management System, other LRSs, or reporting tools. The specification provides a data model and associated components to be used by an Activity Provider to create and tract learning experience. A Learning Record Store can be a subsystem of a larger application or a standalone system; indeed, LRS is a suitable device for managing certain aspects of learning experience.

Learning Design and Learning Activity Management System

There are two main technologies for modeling educational/learning activities online: IMS Learning Design standard (IMS Learning Design Specifications) and Learning Activity Management System (LAMS Foundation). IMS Learning Design (IMS LD), which has three levels (A, B, and C), enables implementation of educational activities. Level A defines the basic entities or elements: activities, roles, and learning objects or services. Level B of the specification allows greater control and complexity through the use of properties and conditions for storing information about a person or group and for placing constraints on the flow of activities. Level C offers the opportunity for more sophisticated learning designs through notifications, which allow new activities to be triggered automatically in response to events in the learning process. Currently, there are no open source learning design systems that implement the IMS LD standard, but the LAMS is widely deployed as a system for authoring, delivering and monitoring learning activities. Using LAMS or an IMS LD based system, students activities and interactions data will be stored as part of the learning artifacts and be available for playback during an education audit.

Content packaging of Learning, education, and training

(ISO/IEC 12785, 2009) describes the data structures for exchanging data between systems that wish to import, export, aggregate, and disaggregate packages of learning, education, and training (LET) content. It is based on the IMS Content Packaging specification (IMS Content Packaging, 2007), which was developed to facilitate packaging and exchange of instructional content. The specification provides means of describing content that is associated with a learning activity, the location of the components of the content, and the content structures, which define the different ways in which content components are to be organized and presented. Figure 2, taken from (SCORM-CAM, 2006), is a conceptual representation of a package.

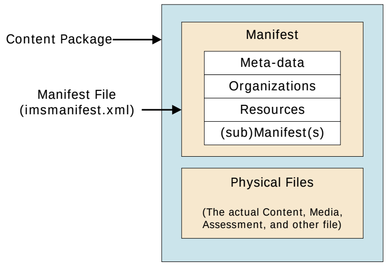

Figure 2: Conceptual Representation of IMS Content Package

A Content Package consists of two major components at the top level—a special XML file (called manifest file) describing the content structure, together with the associated resources, and the physical files that make up the content package. The Content Aggregation metadata describes the content aggregation (i.e., the content package) as a whole at the manifest level; every other level in the hierarchy also has a metadata. Currently, IMS Content Packaging is also being used for packaging data other than instructional content. IMS Content Packaging is a basis for other IMS Specifications such as the IMS ePortfolio Information Model. IMS ePortfolio Information Model (IMS ePortfolio, 2005) is a specification defined to ensure portability of ePortfolios, which is the integration of evidence about learning over time. Portability of Portfolios is achieved through IMS Content Package. Thus, a Portfolio is a collection of portfolio components that are organized in IMS Content Package specification format. The IMS specification can be used to organize learning artifacts associated with students' performance and achievement.

Data cubes as a device for managing the record of learning data

Multidimensional data cubes have been used successfully in modeling business data. In an earlier report (Ola et al., 2014), we showed how learning data can be depicted with multidimensional data cubes. To use the language in RDF Data Cube Vocabulary (RDF Data Cube Vocabulary, 2013), a data cube is organized according to a set of these components: dimensions, attributes and measures. The attribute components allow the observed value(s) to be qualified and interpreted; they enable specification of the units of measure, any scaling factors and metadata such as the status of the observation (e.g. estimated, provisional). The dimension components are used to identify the observations, while the measure components represent the phenomenon being observed. A representation of the cube is presented in Figure 3; the performance indicators stored in the Measure table can be analyzed with respect to the dimensions (Student, Learning Task, and Time dimensions).

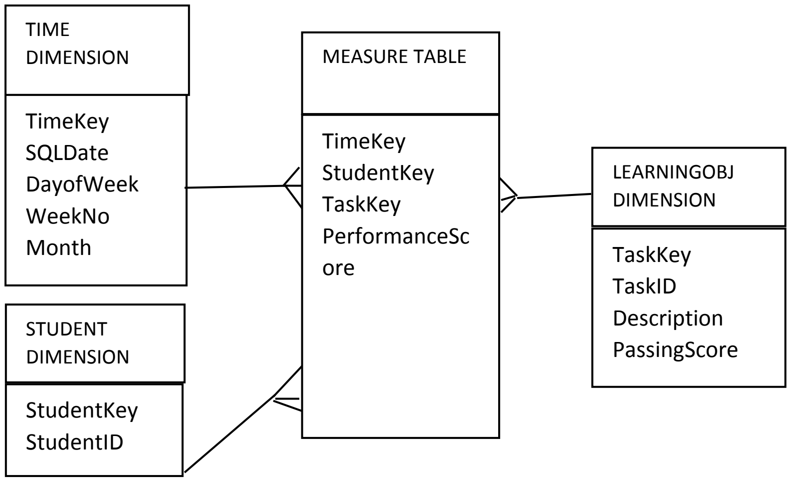

Figure 3: A 4-Dimensional Data Cube of a Learning Environment

With this model, an analysis can provide answers to such questions as: How much improvement has a student made over a period with respect to certain tasks or which learning objectives have not been met by the student?

Temporal Data Management Systems

A database management system that has the capability to manage data across time dimensions is proposed as the implementation software. Temporal database management capability will allow learning artifacts data to be exposed across time dimension to enable answers to questions about what students have accomplished at specific points in time or over time periods. The recent standard (SQL:11-Foundation, 2011) defines the technology that supports modeling of time. Particularly, the new standard supports *system time*, which tracks when changes are made to data tables, as well as *valid time*, which defines the time period for which data is valid.

CONCLUSION

The paper has put forth a new paradigm for assessing students' readiness for target courses or grade levels. It proposes the use of record of learning as a means of establishing the competency and skills of leaners over time, and presents implementation devices for maintaining record of learning data. The ultimate aim of the research is to develop an education audit system that will make it possible to determine, from historical learning artifacts data, how a student arrived at his or her skill level. In cases where the students' knowledge and skills lag considerably behind their assigned grade level, rather than the usual assessments, it may become necessary to perform a complete education audit using the record of learning data.

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