Enhancing the Experience Application Program Interface (xAPI) to Improve Domain Competency Modeling for Adaptive Instruction

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ABSTRACT
This paper describes methods for enhancing the experience application program interface (xAPI) to improve the assessment of domain competency modeling for adaptive instruction. xAPI is an e-learning software specification which allows individual learning experiences and achievements to be amassed in a Learning Record Store (LRS). Adaptive instruction includes tailored training or educational experiences usually delivered and guided by Intelligent Tutoring Systems (ITSs). ITSs can more effectively tailor or adapt instruction when they have more accurate models of the learner's prior knowledge or competency. This paper examines the potential effect of methods to more accurately model learner experiences and domain competency in an LRS. Specifically, we recommend five methods to improve xAPI statements by documenting: 1) achievement types; 2) experience duration; 3) experience source information; 4) domain learning and forgetting; and 5) assessment within learning experiences.

Author Keywords
distributed learning; distance learning; mobile learning; eXperience application program interface (xAPI); learning record store (LRS); intelligent tutoring system (ITS); adaptive instruction; competency modeling

INTRODUCTION
Modeling user experience has long been part of the fabric of Intelligent Tutoring Systems (ITSs) as primary tools for adaptive instruction. Kalyuga, Chandler & Sweller [1] suggested that differing levels of learner experience should be considered when selecting an appropriate user-adapted instructional design. These findings are intended to guide ITS design and multimedia course design through the selection of content (e.g., diagrams, audio, or text) and management of each learner's cognitive load.

L@S 2017, April 20 - 21, 2017, Cambridge, MA, USA
ACM 978-1-4503-4450-0/17/04
DOI: http://dx.doi.org/10.1145/3051457.3054001

Under the auspices of the Advanced Distributed Learning Initiative, the US Department of Defense defined the Shareable Content Object Reference Model (SCORM) as an interoperability standard for online learning [4]. Since SCORM was established prior to the widespread adoption of mobile devices, it was necessary to update the standard to support smartphones, tablets, and other mobile devices.

The experience application program interface (xAPI) is a specification which can be used by a wide variety of instructional technologies (e.g., mobile learning, Intelligent Tutoring Systems (ITSs) or distributed simulations for training) as well as traditional online learning systems to capture data about a broad range of individual learning experiences (e.g., online or offline instruction, reading, or on-the-job training). This includes both formal (e.g., education or training) and informal learning experiences (e.g., reading or games).

Just as SCORM was quickly adopted by the online learning community, xAPI has been rapidly adopted by the mobile learning community as an international standard. The ADL Initiative now has plans to make xAPI the centerpiece of its training and learning architecture (TLA), a collaborative landscape of content providers and consumers. In TLA, providers will be responsible for populating learner achievements in a record store through xAPI statements. The completeness of those statements will form the basis of a long term learner model that can be accessed to populate domain competency just prior to new learning experiences.

xAPI statements format data about a person or group's activities from various sources in a consistent manner and include an actor, a verb, an object, a result, and context [9]. These xAPI components are briefly defined in the next section [9, 10]. xAPI statements may support the modeling of domain competency, an individual's level of proficiency at performing tasks successfully or efficiently in a particular area of expertise (e.g., mathematics). Competency may be viewed as the expectation or potential to perform in the future based on knowledge and skill accumulated in the past (e.g., an expert is expected to perform at a high level while there are lower performance expectations for novices).

Adaptive instruction is the tailored delivery of computer-based training or educational content to learners according to their personal learning needs/gaps. The learner's level of domain competency may be one of the factors considered by an Intelligent Tutoring System (ITS) when adapting instruction, but most ITSs (e.g., AutoTutor or Cognitive Tutor) tailor the instruction based on the learner's recent previous performance rather than long term states like competency.

The level of competency influences adaptation (instructional decisions and actions) by artificially-intelligent tutoring systems. We are specifically examining opportunities to expand the competency assessment capabilities of the Generalized Intelligent Framework for Tutoring (GIFT), a computer based architecture with design goals to improve ITS adaptation and effectiveness [7]. For example, an individual (or group's) level of competency may be used to set expectations for learning and performance during subsequent tutoring experiences so it is important to understand and measure domain competency more precisely than it has been in the past when the primary driver of adaption in tutors was near term modeling of performance.

xAPI statements may help in defining individual or team competency, but could be improved to provide a more accurate picture of both individual and group domain knowledge and skill. The authors are recommending a set of additions/modifications to the existing xAPI specification with this goal in mind. Next we present rationale for what might be needed to fully and accurately define domain competency for computer-based adaptive instruction. Some of these attributes discussed below are already represented within the xAPI specification, while others are not. Before discussing the elements of a competency model, we review the basic elements of an xAPI statement.

Elements of an xAPI Statement

The following are the five components of an xAPI statement [10]:

- Actor: an individual or a group that does something. An actor is required for each xAPI statement. In the statement, "Bob completed the algebra course", "Bob" is the actor.
- Verb: identify the actions of the actor(s). In the statement, "Rodney created a webpage", created is the verb.
- Object: is the thing that is acted upon by the actor. The object can be an activity, agent or group, or a sub-statement. In the statement, "Ben completed the boating course", the object is "boating course" (an activity). In the statement, "The course manager assessed Bob", the object is "Bob" (an agent). In the statement, "Rodney reviewed Ben's final exam", the object is "Ben's final exam" (a sub-statement).
- Result: a measured outcome (completion, success, response or duration). Results are optional. In the statement "Bob scored 92% on the final exam", the result is "92% on the final exam."
- Context: the conditions under which the activities took place. Context is optional. In the statement "Rodney and Ben completed a flying lesson in rainy conditions", the context is "rainy conditions."

ELEMENTS OF A COMPETENCY MODEL

Werkenthin [9] argues "you should always try to use built-in properties of an xAPI statement before creating extensions. Otherwise, you may sacrifice the analytical abilities of your Learning Record Store (LRS). For example, if you created an extension for *score* instead of using the built-in score property of *result*, your extension for *score* may not be included in reports." For this reason, we annotated the competency model schema discussed below as to whether they are an existing part of the xAPI specification or a new recommended extension. Our goal here is to identify and argue the merit of changes to be included in the xAPI specification. So, what is needed to fully understand/measure a learner domain competency at any given time over the course of a career?

We identified five information classes in the literature associated with domain competence: 1) achievement types; 2) experience duration; 3) experience source information; 4) domain learning and forgetting; and 5) assessment within learning experiences. Each of these classes and their associated subclasses is discussed below.

Documenting Achievement Types

The ability to capture a variety of learning achievements based on domain experiences (e.g., instruction, reading or practice) is at the core of the xAPI specification and contributes to the assessment of domain competence. While there are no recommended changes with respect to domain achievements, there are design considerations for implementation in ITS architectures like GIFT. The first consideration is how GIFT will generate xAPI statements for achievements accomplished in GIFT-based tutors. The second consideration is how GIFT will be enabled to consume xAPI statements and use them to adapt instruction.

GIFT is currently enabled to generate xAPI statements when lessons or courses are completed. It might be useful to generate statements for more fine grained achievements (e.g., correct answers to individual questions or problems). Future versions of GIFT will be designed to consume xAPI statements from an LRS to determine domain competency prior to instruction in that domain. GIFT will require mechanisms to read the statements and conduct competency assessments to determine course flow, options to skip course lessons, and selection of strategies to optimize the learning experience.

Documenting Experience Duration

Currently, the xAPI specification supports the generation and storage of domain achievements including a completion date and time. While the specification provides the ability to generate information about the duration of domain experiences, it is critical to be able to sum contact hours (time in the learning experience) over a series of separate events. In other words, we need to be able to track cumulative participation in a learning experience. For example, the contribution of a one hour tutorial on algebra toward mathematics competency is much different than a one week course involving 5 one hour sessions, or a semester long course with 45 one hour sessions, or a four year degree program in mathematics involving thousands of class sessions, lab sessions, and homework sessions. This function might be enabled by adding two elements called "session completion" and "part of" to the result specification. In the example below, the learner completed a one hour session of a semester long math course with no assigned score for the session.

```
"result": {
   "session completion": true,
   "duration": 1 hour,
   "part of": semester math course,
   "success": true,
   "score": {
     "not applicable"
```

This result might be used in conjunction with an xAPI object denoting the topic studied during the session (e.g., quadratic equations). GIFT-based tutors would use this information and information in the subsequent sections to determine an overall domain competency (e.g., low, moderate, or high).

Documenting Source and Quality of Domain Experiences

Just as the varying duration of a learning experience has varying influence on domain competency so does the source of learning experiences. Currently, the xAPI specification generates and stores messages which identify the source of domain experiences, but has no mechanism for assessing the quality of the experience. While it is possible for external systems to act on the xAPI source information to make a determination of quality, it would be convenient to have the each source rate the learner's experience based on the effectiveness of its curriculum, the duration of the experience and the level of assessment inherent to the system providing the experience. A standard method for generating this assessment is desirable for consistency.

Modeling of Domain Learning and Forgetting

As discussed above, assessed domain experiences have quantifiable contributions to domain learning and competency. During learning experiences, memory of domain information is strengthened, but once the last learning experience in a particular domain ends, forgetting begins (Figure 1) [8].

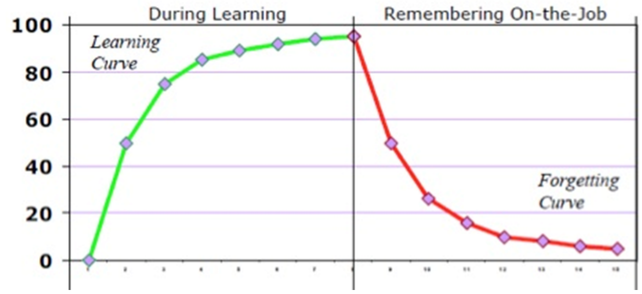

Figure 1. Typical Learning and Forgetting Curve: during learning events (e.g., instruction, reading, practice), memory for domain information is strengthened [8].

For example, a learner completes a course in calculus at age 20. The learner's performance at 30 is likely to be much lower without any intervening practice.

Also the highest level of learning achieved in a domain may result in differing rates of forgetting. For example, a learner who did not reach full competency has less knowledge and skill than someone who is fully competent. While forgetting rates may be the same, the level of forgetting is different at any given time because each individual began the forgetting process with different levels of learning.

For this reason, the level of knowledge and skill decay is critical to assessing domain competency and is not currently represented in the xAPI specification. Also important to learning and forgetting is the understanding of when learning decays to a point where refresher training is needed. This could be part of the result specification in xAPI statements as follows:

```
"result": {
   "completion": true,
   "duration": 1 hour,
   "success": true,
   "score": 92
   "refresher needed": one year after completion
```

Modeling Assessment of Domain Experiences

What is assessment and why should it be represented in xAPI statements? Assessments are methods used to understand the nature, quality, or ability of someone or something. Assessments may include oral or written tests (also called checks on learning). The quality of learning may be different for experiences that are assessed versus those that are not assessed, but learning can still occur during unassessed/informal experiences (e.g., reading). The accuracy of the understanding of a learner's domain competency may also be affected by the validity of the assessment used. Assessment is an activity type that is part of the xAPI specification and may be used to determine domain competency. The use of unassessed experiences, however, may require some generalized rules to determine their influence on domain competency. For example, an hour of unassessed reading in a domain is recognized as a learning experience and contributes “X” to domain competency. Each of these generalized rules could be updated based on their effect on learners leading into future assessed learning experiences.

NEXT STEPS IN THE APPLICATION OF XAPI IN GIFT

As noted earlier, GIFT is already enabled to generate xAPI statements, but will require specifications to generate statements at various levels of granularity (e.g., course completion, lesson completion, or action completion). Mechanisms must also be developed to consume xAPI statements and to use them for both pre-course recommendations and real-time adaptations for the selection of content, feedback, and interactions with the tutor. Pre-course recommendations might include future learning opportunities based on the learning in previous experiences.

Data analytic capabilities in GIFT should also be targeted to continuously evaluate the effect of decisions based on xAPI statements leading to future design changes and improvements. For example, as GIFT transitions from a rule-based to an agent-based framework, tutor decision will be improved over time through reinforcement machine learning techniques.

We also want to expand the diversity of training domains to which xAPI statements are applied [3]. Most ITSs are currently focused on well-defined, procedural tasks predominately teaching mathematics, physics, and computer programming. The ability to apply ITS technologies to psychomotor and social/collaborative task will increase their relevance as instructional tools.

In particular, the ability to assess learners and adapt instruction for teams will make ITSs useful as tools for self-regulated learning in large organizations (e.g., corporations and military organizations) where teams are the common denominator for pursuing goals and executing missions. The application of ITSs to team training domains will require the assessment of achievements at the team level as well as the individual learner level both in the near term (within a training session) and the long term (across multiple training experiences).

Finally, we have a goal to standardize the assessment of competency levels based on achievement statements instantiated via xAPI statements. The development of a competency index to assess long term modeling of skills in a variety of domains would be useful complement to the real-time behavioral analysis used to assess performance levels in cognitive, psychomotor, and social taxonomies [2, 5, 6].

ACKNOWLEDGEMENTS

The research described herein has been sponsored by the U.S. Army Research Laboratory. The statements and opinions expressed in this article do not necessarily reflect the position or the policy of the United States Government, and no official endorsement should be inferred.

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