

# Developing Standards for Adaptive Instructional Systems: 2018 Update

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## INTRODUCTION

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At a learner modeling expert workshop held at the University of Memphis in 2012, Robson and Barr discussed the potential of lowering the barriers to adopting intelligent tutoring systems (ITSs) through standardization and subsequently wrote a chapter about market needs and standards for learner modeling (Robson & Barr, 2013). Fast forward five years and the University of Memphis and US Army Research Laboratory brought together a group of ITS stakeholders from the IEEE standards association, industry, government, and academia in November 2017 to discuss potential standards across ITSs and other intelligent media that we labeled *adaptive instructional systems (AISs)*. Sottolare & Brawner (2018) define AISs as: *computer-based systems that guide learning experiences by tailoring instruction and recommendations based on the goals, needs, and preferences of each learner in the context of domain learning objectives.*

Based on the stakeholder meeting in November 2017, the IEEE Learning Technologies Standards Committee established a 6 month AIS standards study group. An essential role of this study group is to engage AIS stakeholders to understand the marketplace needs and identify opportunities to reduce barriers to adoption through standardization. As part of their activity, the AIS study group established four workshops to engage stakeholders:

- First AIS Standards Workshop – 7-8 March 2018, Orlando, Florida
- AIS Standards Workshop at the Generalized Intelligent Framework for Tutoring (GIFT) Users Symposium – 11 May 2018, Orlando, Florida
- AIS Standards Workshop at the Intelligent Tutoring Systems Conference – 12 June 2018, Montreal, Canada
- AIS Standards Workshop at the Artificial Intelligence in Education Conference – 30 June 2018

The purpose of this paper is to highlight some of the ideas and opportunities for standards identified through the development and conduct of these workshops.

## POTENTIAL AIS STANDARDS

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This section identifies some of the ideas put forth as opportunities for standards and discusses their merit with respect to the following criteria:

- the idea solves a specific problem identified by AIS developers and/or users
- the idea reduces the time and skill required to develop AISs
- the idea promotes opportunities for interoperability and reuse without negative impact on intellectual property
- the ideas promotes opportunities for new AIS markets or collaboration opportunities

## **Common AIS Conceptual Model**

Robson, Sottolare & Barr (2018) identified the need for an AIS conceptual model including definitions, common components, and functions. They states that “a hierarchical common understanding of the composition of AISs would be useful in communicating ideas in lectures, presentations, and technical papers as well as system specifications”. While this proposal will stir some debate, it seems that a common conceptual model of AISs is low hanging fruit that could be implemented quickly as a standard. The likely results of this proposal being a reduction in development time and expanded opportunities for collaboration based on a greater common understanding of AIS design.

## **AIS Component Interoperability and Reuse**

Three workshop papers have suggested standards opportunities based on component interoperability (Sottolare & Brawner, 2018a; Brawner & Sottolare, 2018; Sottolare & Brawner, 2018b). The basis for this proposal is the fact that the literature is fairly consistent in identifying four common components or models within ITSs: domain, learner, instructional (or pedagogical), and user interface. While the functions contained within these components can vary widely among ITSs, the data they exchange and act upon are fairly consistent. Domain models generally provide assessments of the learner’s progress toward learning objectives to the learner model. In addition to learner performance, the learner model contains a large number of learner states (e.g., affect, engagement, interest, and preferences). The instructional model receives information about the learner’s states and uses this to recommend next steps in the instruction. A user interface model collects information about the learner that can be used to ascertain their current and future states. A standard set of messages could be easily implemented and allow for the swap of one component for another more appropriate or effective component without redesigning the AIS.

Another aspect of component interoperability is AIS compliance with external “standards” like the experience application program interface (xAPI) which generates statements of achievement based on formal and informal education and training experiences (Sottolare, Long & Goldberg, 2017) or the learning tools interoperability (LTI) standard which enables data exchanges with courses in learning management systems (LMSs) like edX, Canvas, and Blackboard to support adaptive massive online open courses (MOOCs; Alevan et al, 2018). Durlach (2018) has suggested that adoption of standards like National Information Exchange Model (NIEM) could also facilitate interoperability. More work is needed to identify potential use cases and existing standards in which we wish AISs to interoperate with.

## **Learner Modeling Standards**

Robson & Barr (2013) mention a previous effort to develop IEEE standards to enable learners to build a personal learner model, to enable developers to provide more personalized instruction, to provide standard sources of data to researchers, to enhance the learner-centric design of instructional systems, and to provide architectural guidance for instruction system designers. However, they also note that this noble effort never resulted in a standard. For this reason, Robson & Barr (2013) have suggested that learner information be standardized, but not the learner model itself or any other model within ITSs.

Several workshop papers have proposed learner modeling standards. Baker & Coleman (2018) have recommended that a yet-to-be-specified set of behavioral models be standardized to represent learner engaged and disengaged behaviors. Biswas & Rajendran (2018) have suggested a three-tiered learner model to represent metacognitive processes, cognitive strategies, and cognitive skills. Rus (2018) and Tackett et al (2018) note the need to standardize the representation of a learner’s knowledge (prior, current, and predicted).

Another idea discussed during recent AIS standards workshops and meetings has centered on learner records which contain a set of common features that could form the basis of a default learner model. Learner record features could include demographic data, historical records of experience and achievement, and a longer term model of domain competency along with associated models of skill decay. Standard learner record fields would allow systems other than the originating system to read in and interpret learner data in support of new instructional experiences (Robson, Sottolare, & Barr, 2018).

## **Domain Modeling Standards**

Much fewer stakeholders have put forward ideas for standardizing domain models and their associated content, but “*it is content and domain modeling that most subject matter experts think about when they create curricula and learning environments*” (Hu, Graesser, & Cai, 2018). We believe this points to the need for a methodology to structure domains models and content as a framework in which old domain knowledge and content can be swapped out to the system for old, less effective content. They also recommend that domain models and content be aligned with the developers mental model of the process and be sufficiently specified so as to be functional and effective. McCoy (2018) also suggests a structured domain model based upon hierarchical relationships.

## **Validation Standards**

The idea of validation standards was extracted from Robson, Sottolare, & Barr (2018). “Once standards have been adopted for common conceptual models, component interoperability, and learner record features, we will not only want to validate AIS compliance to those standards but will also want to test their effectiveness, their fit for purpose, and their compatibility with other learning systems. Support for other standards, such as the experience API (xAPI) must be considered, and authors of AISs may desire to evaluate the effectiveness of their systems as a whole or in part to understand how their product stacks up against marketplace expectations for performance and learning effectiveness”.

Examples of this type of *testbed* or *quality function* can be found widely. In the 1990’s compliance testbeds were established to support interoperability testing for both IEEE 1278 Distributed Interactive Simulation (DIS) standard and IEEE 1516 High Level Architecture (HLA) standard to allow participants in large scale distributed simulation training exercises and experiments to gauge their readiness to be compliant with the standard, interoperable with other federates, and compatible with the simulation information required to be exchanged between federates.

Early in its development, US ARL adopted a testbed function for GIFT to support experimental evaluation of its components to determine whether they met validation criteria. Our experience with GIFT may serve as a model for how we might approach validation, and therefore serve as a guide to normative language in a broader series of standards that address the quality of AISs and their compatibility with other learning systems.

## **NEXT STEPS**

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The next steps are to complete the approved workshops and begin to share a work program for our potential IEEE working group. A project authorization request (PAR) has been formulated and submitted to the IEEE Learning Technologies Standards Committee. According to IEEE, “a PAR is a legal document and the means by which a working group assigns copyright to and indemnification from IEEE. Every PAR that is submitted must have a Sponsor to oversee the project. A PAR is a document that states the reason for the

project and what it intends to do”. The specific PAR for AIS standards is P2247.1 and the PAR and our request to establish an AIS Working Group are up for approval with an expected decision in July 2018.

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## REFERENCES

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- Aleven, V., Sewell, J., Popescu, O., Sottolare, R., Long, R., & Baker, R. (2018, June, *in press*). Towards Adapting to Learners at Scale: Integrating MOOC and Intelligent Tutoring Frameworks. In Proceedings of the Learning @ Scale Conference, London, England, June 26-28, 2018.
- Baker, R. & Coleman, C. (2018, March, *in press*). Standardizing Modeling of User Behaviors: Which Behaviors Matter? In Proceedings of the *First Adaptive Instructional Systems (AIS) Standards Workshop*, Orlando, Florida.
- Biswas, G. & Ranjendran, R. (2018, March, *in press*). Standardizing Learner Modeling for Complex Domains Using Multi-Level Learner Modeling Schemes. In Proceedings of the *First Adaptive Instructional Systems (AIS) Standards Workshop*, Orlando, Florida.
- Brawner, K. & Sottolare, R. (2018, June, *in press*). Proposing Module-level Interoperability for Intelligent Tutoring Systems (ITSs). In the Exploring Opportunities to Standardize Adaptive Instructional Systems (AISs) Workshop of the 19th International Conference of the Artificial Intelligence in Education (AIED) Conference, London, England, United Kingdom, June 2018.
- Durlach, P. (2018, March, *in press*). The Potential of the National Information Exchange Model (NIEM) for Standardizing Adaptive Instructional System Information Exchange and Domain Knowledge. In Proceedings of the *First Adaptive Instructional Systems (AIS) Standards Workshop*, Orlando, Florida.
- Hu, X., Graesser, A., & Cai, Z. (2018, March, *in press*). Standardizing Content and Domain Models in Intelligent Tutoring Systems: A Few Ideas. In Proceedings of the *First Adaptive Instructional Systems (AIS) Standards Workshop*, Orlando, Florida.
- McCoy, D. (2018, *in press*). Domain models, student models, and assessment methods: three areas in need of standards for adaptive instruction. In the Adaptive Instructional System (AIS) Standards Workshop of the 14th International Conference of the Intelligent Tutoring Systems (ITS) Conference, Montreal, Quebec, Canada, June 2018.
- Robson, R. & Barr, A. (2013). Chapter 2 – Lowering the Barrier to Adoption of Intelligent Tutoring Systems through Standardization. In R. Sottolare, A. Graesser, X. Hu, & H. Holden (Eds.) *Design Recommendations for Intelligent Tutoring Systems: Volume 1- Learner Modeling*. US Army Research Laboratory, Orlando, Florida. ISBN 978-0-9893923-0-3.
- Robson, R., Sottolare, R. & Barr, A. (2018, June, *in press*). Examining Barriers to the Adoption of IEEE Standards for Adaptive Instructional Systems (AISs). In the Exploring Opportunities to Standardize Adaptive Instructional Systems (AISs) Workshop of the 19th International Conference of the Artificial Intelligence in Education (AIED) Conference, London, England, United Kingdom, June 2018.
- Rus, V., Graesser, A., Hu, X., & Cockroft, J. (2018, June, *in press*). A Computational Perspective of Adaptive Instructional Systems for Standards Design. In the Exploring Opportunities to Standardize Adaptive Instructional Systems (AISs) Workshop of the 19th International Conference of the Artificial Intelligence in Education (AIED) Conference, London, England, United Kingdom, June 2018.

- Sottolare, R. & Brawner, K. (2018a, March, *in press*). Exploring Standardization Opportunities by Examining Interaction between Common Adaptive Instructional System Components. In Proceedings of the *First Adaptive Instructional Systems (AIS) Standards Workshop*, Orlando, Florida.
- Sottolare, R. & Brawner, K. (2018b, June, *in press*). Component Interaction within the Generalized Intelligent Framework for Tutoring (GIFT) as a Model for Adaptive Instructional System Standards. In the Adaptive Instructional System (AIS) Standards Workshop of the 14th International Conference of the Intelligent Tutoring Systems (ITS) Conference, Montreal, Quebec, Canada, June 2018.
- Sottolare, R. A., Long, R. A., & Goldberg, B. S. (2017, April). Enhancing the Experience Application Program Interface (xAPI) to Improve Domain Competency Modeling for Adaptive Instruction. In *Proceedings of the Fourth (2017) ACM Conference on Learning@ Scale* (pp. 265-268), Cambridge, Massachusetts, April 20-21, 2017. ACM. DOI: <http://dx.doi.org/10.1145/3051457.3054001>.
- Tackett, A.C., Cai, Z., Hampton, A.J., Graesser, A., Hu, X., Ramirez-Padron, R., Folsom-Kovarik, J.T., & Copland, C. (2018, June, *in press*). Knowledge Components as a Unifying Standard of Intelligent Tutoring Systems. In the Exploring Opportunities to Standardize Adaptive Instructional Systems (AISs) Workshop of the 19th International Conference of the Artificial Intelligence in Education (AIED) Conference, London, England, United Kingdom, June 2018.

## ABOUT THE AUTHOR

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