Integrating MOOCs and Intelligent Tutoring Systems: edX, GIFT, and CTAT

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Outline

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- Context: Big Data in Education MOOC

- Background: What is CTAT?

- Accomplishments: Integration of GIFT into edX

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Motivation

- MOOCs are successful at delivering courses at scale, often for free

- Some challenges in MOOCs: feedback, individual attention, low retention

  - Proposed solution: add adaptivity

- Integrating MOOCs with intelligent tutoring systems (ITSs) is not always straightforward

  - Existing standards promise this capability

- Possible advantages of integration: more reuse, complementary strengths, wider dissemination

Project Goals

- Provide a novel framework and reproducible exemplar for adaptivity in MOOCs, supported by proven, domain-independent authoring tools for adaptive learning technologies

- Create a highly adaptive MOOC combining the adaptive capabilities of GIFT and CTAT

- Improve an existing online course in educational data mining, a field of growing interest

Why Combine CTAT and GIFT? Complementary Strengths

- Complementary adaptive behaviors
  - GIFT outer loop: chooses material according to assessment, characterized by difficulty, media, user control, etc.
  - CTAT outer loop: chooses only by fine-grained skill probabilities
  - CTAT inner loop: includes step-based problem solving, immediate feedback, multi-level hints, varied solution strategies
- Complementary student models
  - GIFT: concept knowledge, engagement, motivation, anxiety
  - CTAT: fine-grained skills or knowledge components

Context: MOOC on Big Data in Education

Big Data in Education: Online course in Educational Data Mining

Offered twice on edX from Teachers College, Columbia University
Beginning June 19, 2017, on edX from University of Pennsylvania

Big Data in Education Course Topics

Week 1: Prediction

Week 2: Diagnostic Metrics and Cross-Validation

Week 3: Feature Engineering and Behavior Detection

Week 4: Knowledge Inference and Knowledge Structures

Week 5: Relationship Mining

Week 6: Visualization

Week 7: Clustering and Factor Analysis

Week 8: Discovery with Models

Past BDE Iterations: Students, Enrollment, Research

- Over 72,000 students at official course end across iterations

- Several thousand more have accessed material outside of official course runs

- BDEMOOC has been used as a platform for research many times already, resulting in 11 papers

Background: What is CTAT?

Cognitive Tutor Authoring Tools (CTAT): a software suite for ITS development by non-programmers
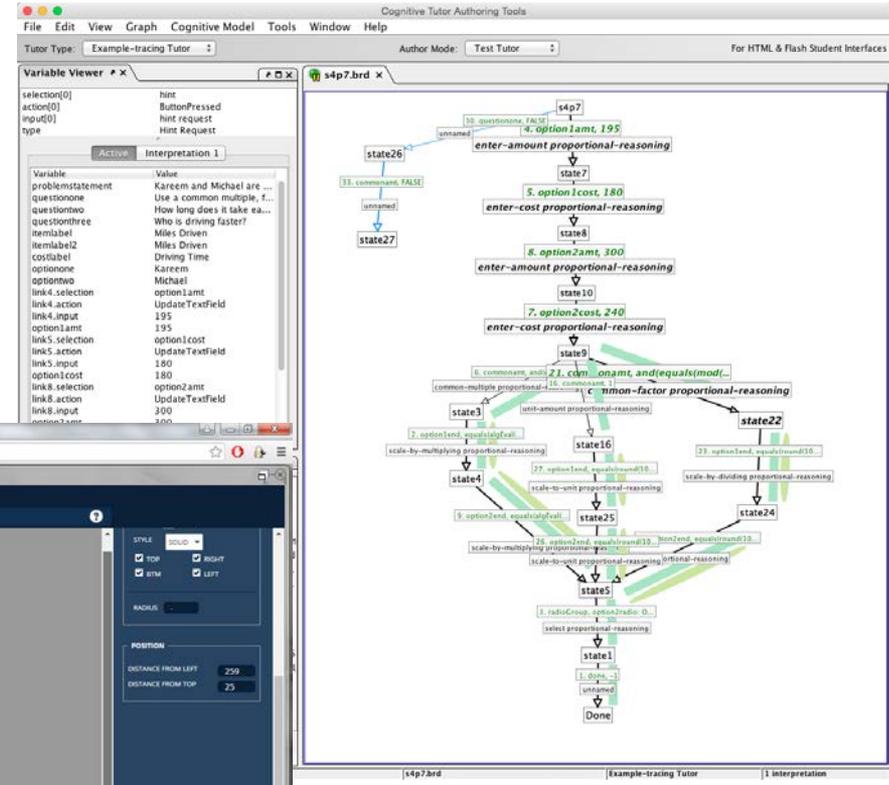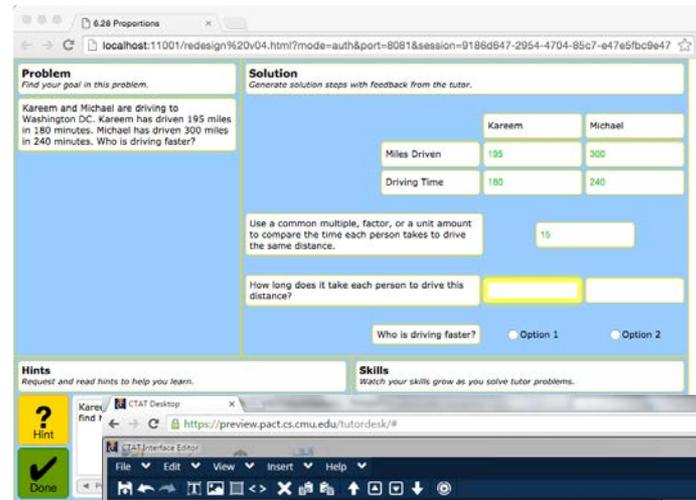
Editable behavior graph created through programming by demonstration
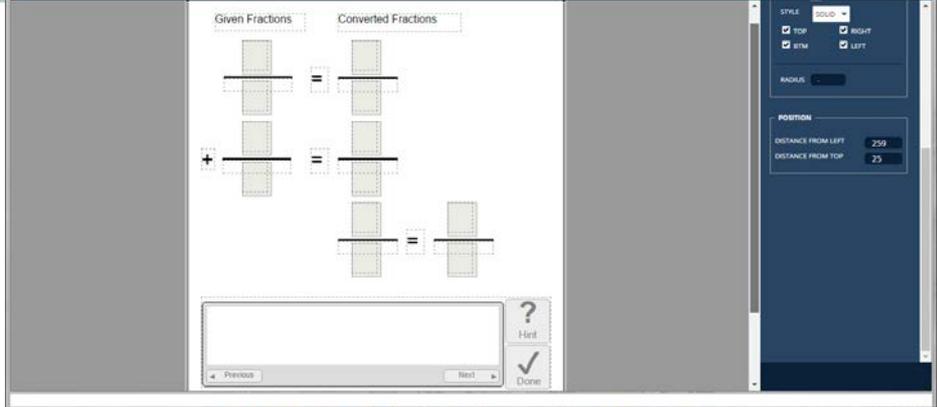
Drag-and-drop HTML editor for creating tutorable interface

CTAT Use and Effectiveness

- Development costs of CTAT tutors 4 to 8 times lower than "historical" estimates of ITS development time and cost (Aleven et al., 2009)

- Has been used by ~650 authors

- Many tutors have been built with CTAT and demonstrated learning gains in classrooms

  - Selected 18 for 2016 IJAIED paper, many more implemented

- CTAT tutors have been used in over 50 studies

Aleven, V., McLaren, B. M., Sewall, J., van Velsen, M., Popescu, O., Demi, S., . . . Koedinger, K. R. (2016). Example-Tracing tutors: Intelligent tutor development for non-programmers. *International Journal of Artificial Intelligence in Education, 26*(1), 224-269. doi:10.1007/s40593-015-0088-2

CTAT Tutors in real educational settings: variety of domains, from grade school to graduate school

Accomplishments:
Integration of GIFT into edX
(and other LTI-compliant LMSs)

Integration via the Learning Tools Interoperability (LTI) Standard

- LTI vs other LMS standards (SCORM, e.g.)
- LTI v1.1 specification
  - API for "Tool Consumer" (LMSs)
  - API for "Tool Provider" (store of learning objects)
  - edX, Coursera, Canvas, Moodle and Blackboard. implement the LTI Tool Consumer interface: GIFT content now available to course authors for those MOOC LMSs

- Our first step: Embed GIFT and CTAT (separately) into edX
  - both must implement the LTI Tool Provider API

IMS Global Learning Tools Interoperability™ Implementation Guide (Final Version 1.1). (2012, March 13). Retrieved from https://www.imsglobal.org/specs/ltiv1p1/implementation-guide

Already an LTI Tool: CTAT Tutor in edX

ARL-Dignitas Implemented the LTI Tool Provider Interface in GIFT

GIFT LTI (v1.1) Tool Provider Launch Request Sequence
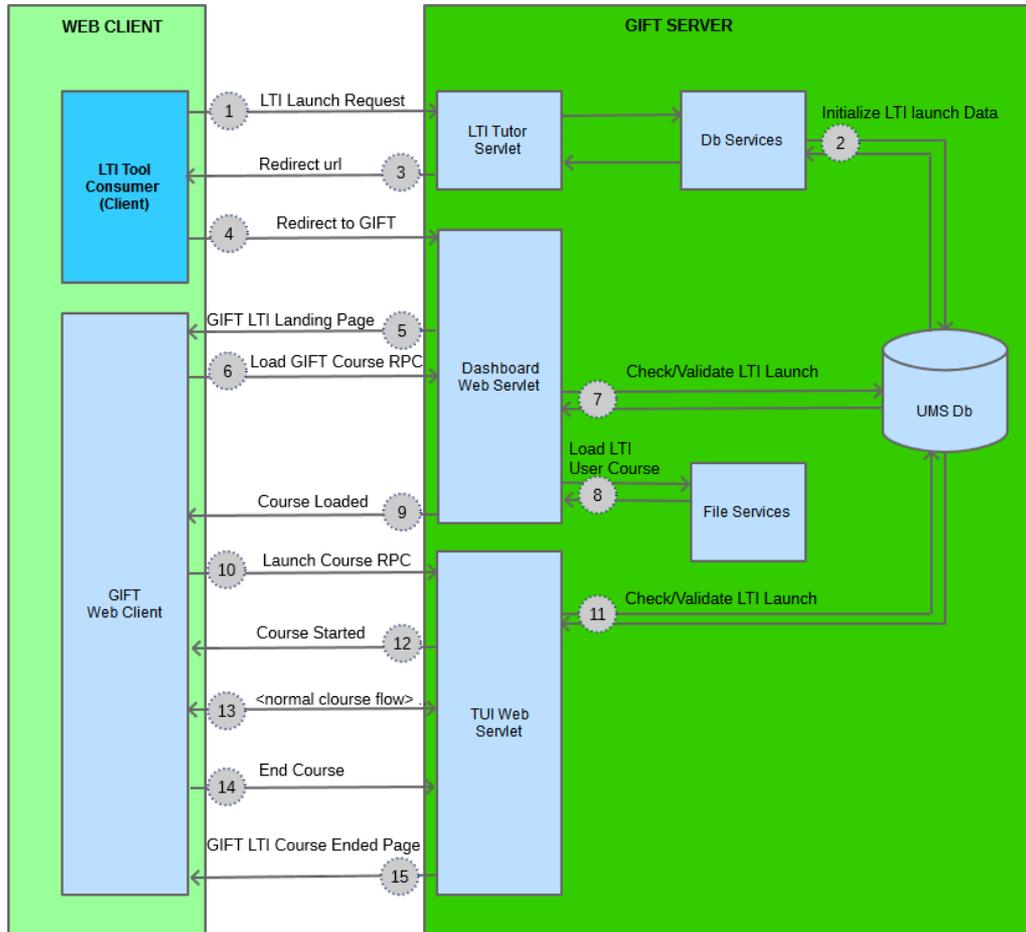
Strategy:

- New servlet fields LTI launch request, authenticates, redirects to GIFT

Challenges:

- LTI users not authenticated. Solution: Servlet validates and stores LTI user info in new database table.

- GIFT URL had path to plain-text GIFT course file name. Solution: Replace file path with universally unique identifier (UUID)

Inserting an LTI Tool instance into edX

- Next is a series of screenshots showing some details of how to embed GIFT into edX or other LTI Consumers
- Unit of integration: entire course or selected problem(s)
- Simple concise instructions on gifttutoring.org:
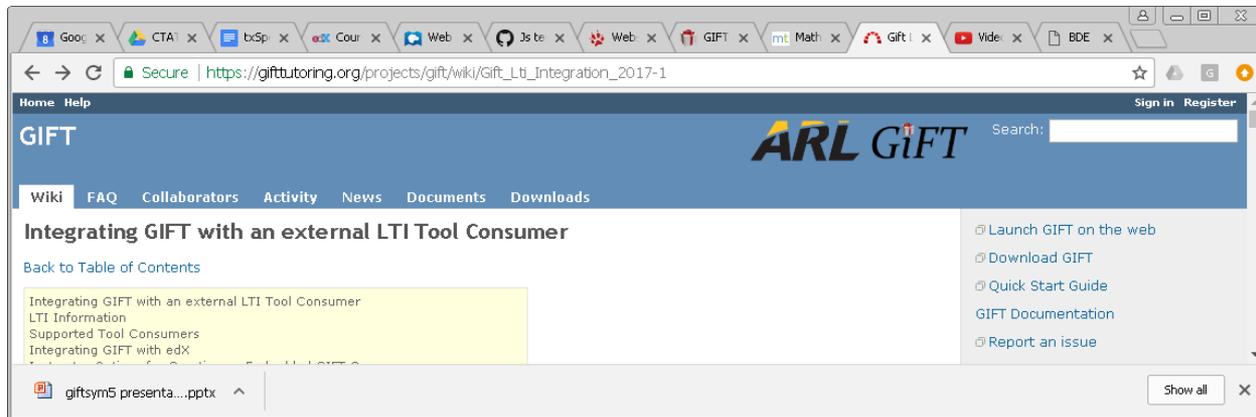
https://gifttutoring.org/projects/gift/wiki/Gift_Lti_Integration_2017-1

Copy LTI Tool credentials into edX, so GIFT will recognize edX launch requests

From https://gifttutoring.org/projects/gift/wiki/Gift_Lti_Integration_2017-1

Choose a proper frame height for the embedded GIFT activity
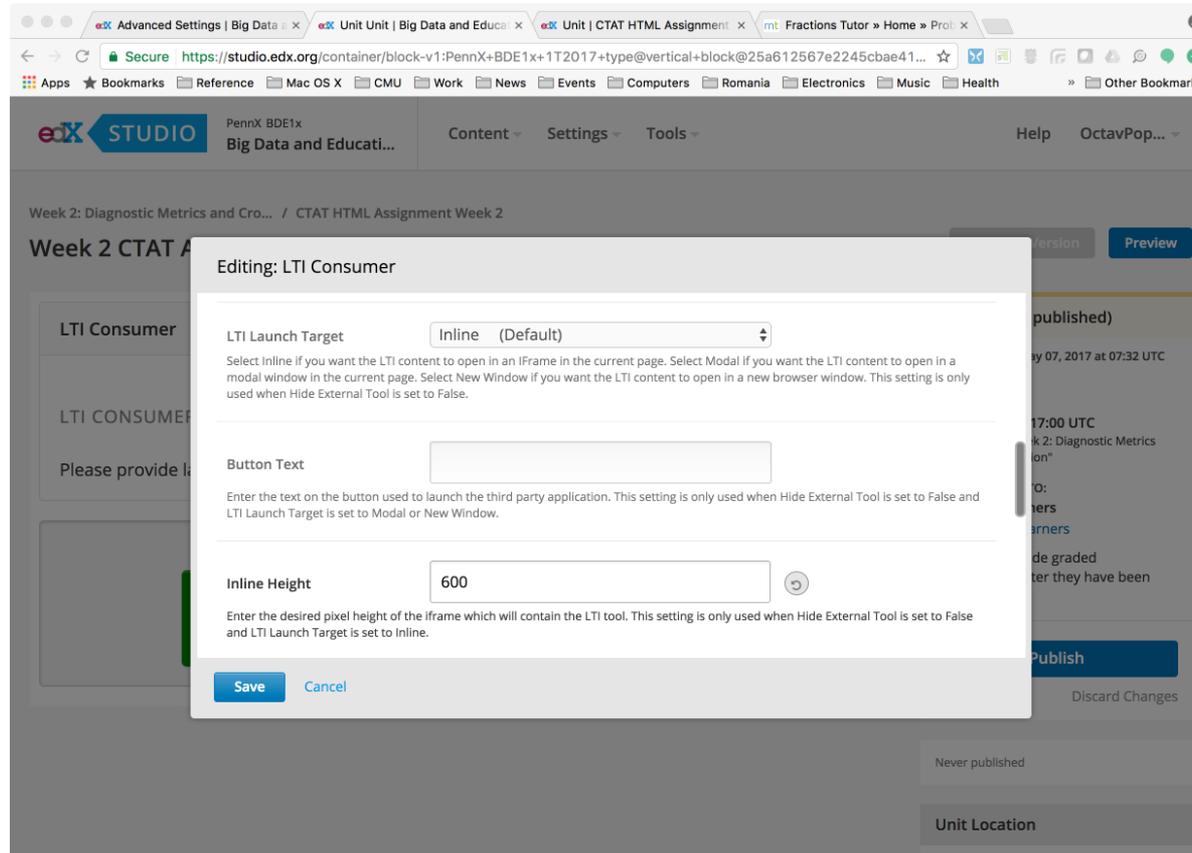
- Height parameter available using newer "lti_component" in edX's Advanced Settings
- Judgment call: large enough to see, small enough for mobiles

Test on mobile devices and desktops
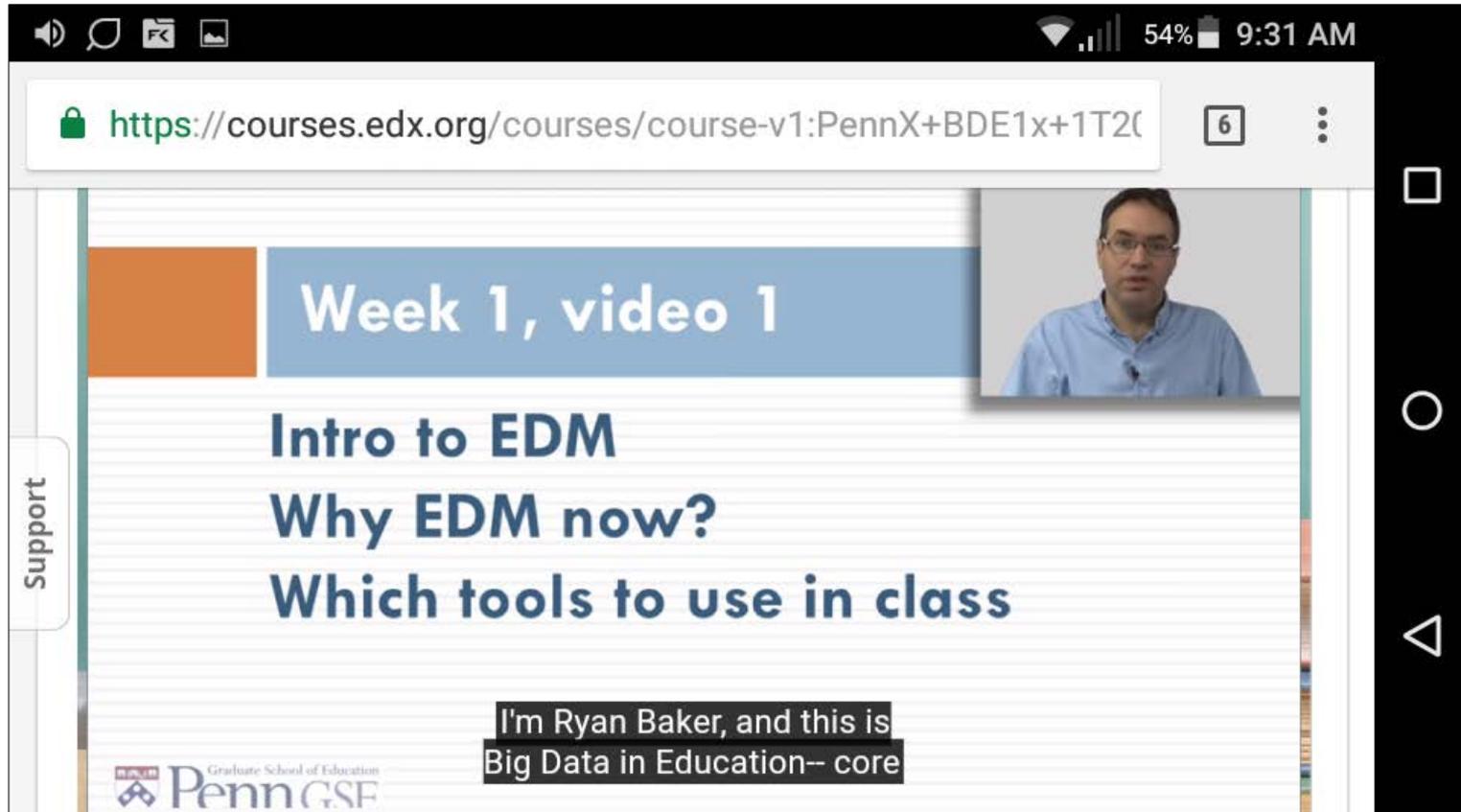
edX accessibility requirements:
- be sure video text, captions remain legible
- navigation buttons should be visible

On-going: Development of additional course content under GIFT-EMAP

Course Content

- Materials drawn from earlier editions of the course offered by Teachers College, Columbia
  - Videos
  - Assignments
  - Discussion Forums
  - Self-organized study groups on Facebook, Linkedin
- Content to be adapted to work with GIFT
- Additional content to be created for these editions of the course, using edX, GIFT, and CTAT

Mapping BDEMOOC Content to GIFT's EMAP Quadrants

BDEMOOC2017 -- CDT matrix

Topic

	Topic	Rules/Exposition	Examples	Recall	Practice	Conceptual	External Resources	
2	Glossary of things we'll cover in more detail later, but you need for {the walkthrough, ba1, ca1}							
3	Course Introduction	V1-1	V1-1	R1-1				
4	Three V's	V1-1 (full re-record)						
5	Diagram of topics in course					Wk 1		
6	What is Prediction	V1-2	V1-2	R1-2		CC1-4		
7	What is Regression	V1-2	V1-2	R1-3, R1-4		CC1-4		
8	Computing a Value for Regression	V1-2	V1-2		V1-2-quiz1			
9	Understanding Contribution of Variable to Model	V1-2			V1-2-quiz2			
10	Variable Transformations	V1-2	V1-2					
11	Benefits of Linear Regression	V1-2	n/a					
12	Risks of Interpretation with Multicolinearity	V1-2	V1-2					
13	Regression Trees	V1-2	V1-2	R1-7				
14	What is Classification	V1-3	V1-5	R1-5, R1-6	W1 (add sao ped	CC1-4		
15	Domain Specificity of Education	V1-3, V1-4	n/a					
16	Variables to Exclude in Classification	V1-3 (slides 49-5!	V1-3		A1 (bde asgn.1 should exclude UNIQUEID; UNIQUEID bug; eliminat			
17	Step Regression	V1-3	V1-3		V1-3-quiz-1 (green), A1			
18	Logistic Regression	V1-3	V1-3, V1-5	R1-7, R1-8				
19	Logistic/Step Regression Limitations	V1-3	n/a			CC1-2		
20	Decision Trees	V1-3	V1-3	R1-8	W1, A1			
21	Decision Tree Benefits	V1-3	n/a			CC1-2		

- Identified concepts for each lecture
- Video lectures became EMAP Rule Quadrant content

New check-for-understanding questions
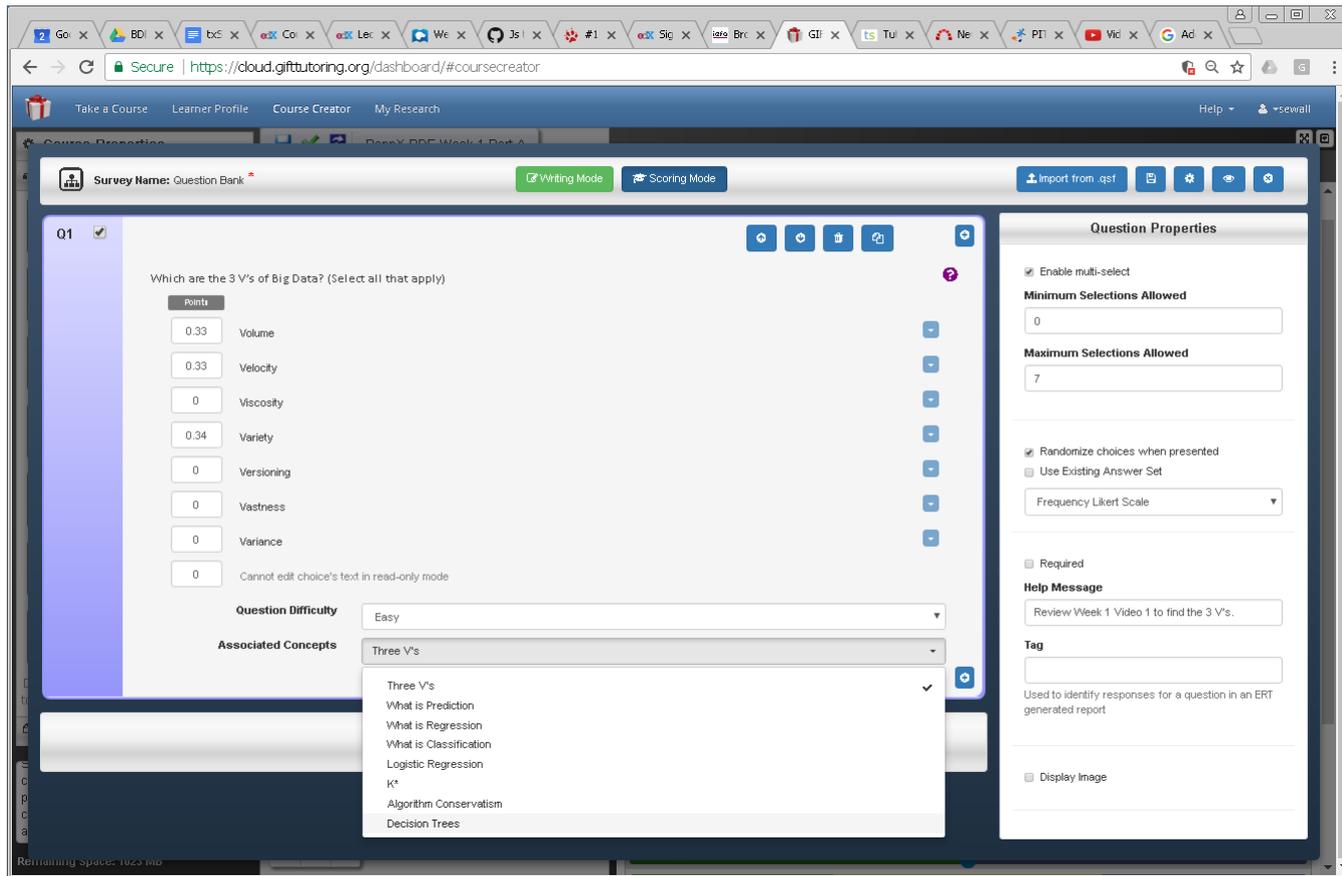
- Added, with scoring and characterization, for EMAP Recall Quadrant

Next Steps: More LTI features in GIFT, direct integration with CTAT

Tighter Integration: Extending GIFT as an LTI Provider

- Give GIFT instructor the option to collect GIFT data on users who took GIFT course via LTI

  - Already available in newer version of GIFT

- Make GIFT report a score to the LTI Tool Consumer

  - Students could see GIFT performance in edX

  - Currently just a single percentage

  - Possibly richer results in LTI v2, but will have to see how many MOOC platforms will support that standard

Making GIFT an LTI Tool Consumer

- Consumer is LMS half of the LTI standard
  - Invokes LTI Tool in iframe, dialogue, browser tab (maybe others)
  - Accepts authentication credentials; provides URLs for grading, saving state
- EMAP can choose and sequence CTAT content directly
- GIFT gains the ability to incorporate *any* LTI Tool
  - 100's of off-the-shelf learning activities are LTI Tools (list of certified tools: https://www.imsglobal.org/cc/statuschart.cfm)
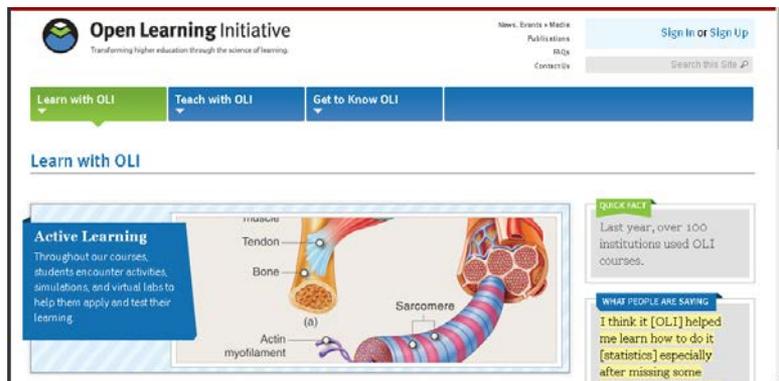
Since some LMSs themselves are LTI Tools, EMAP could route a student to an entire online course, such as those at http://oli.cmu.edu/learn-with-oli/

Planned Integration of edX, GIFT, & CTAT
Configuration as it will exist at the end of the project
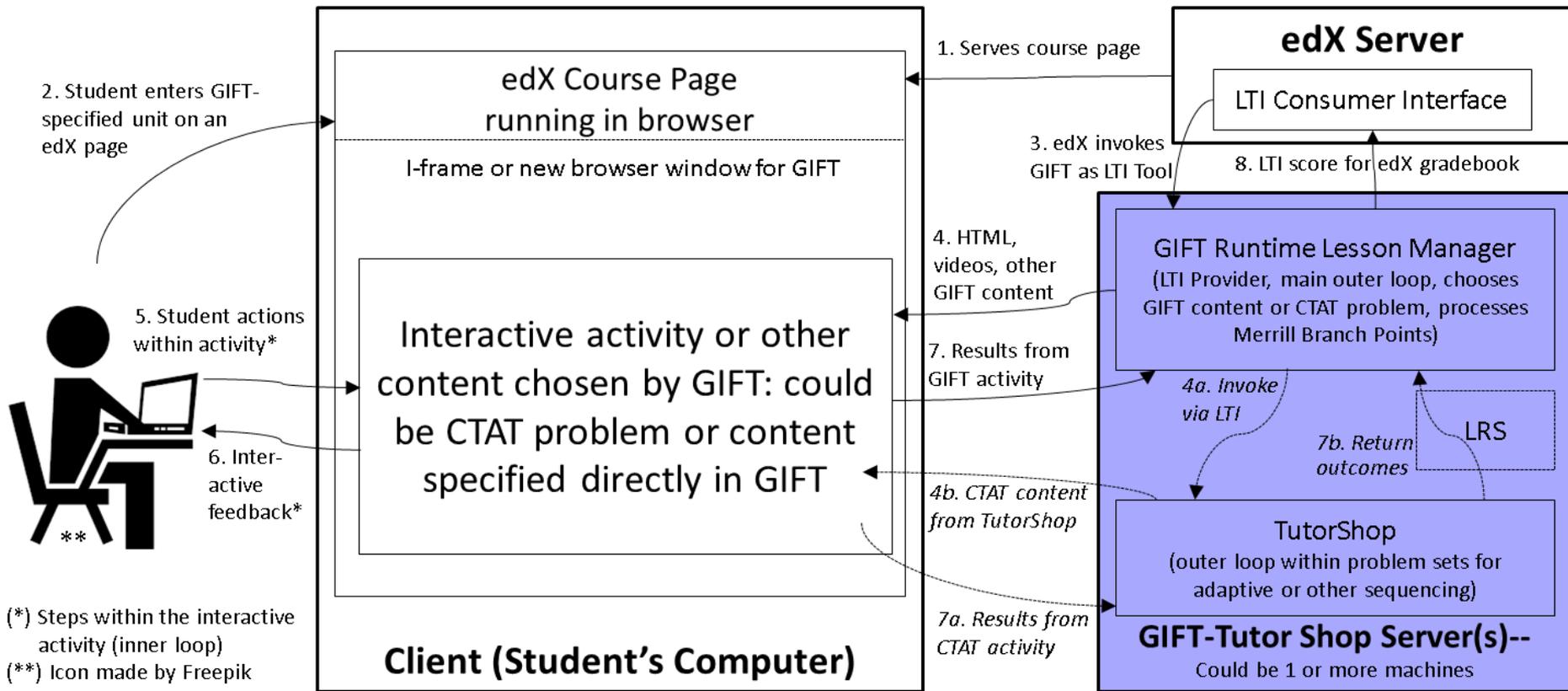
- GIFT-EMAP selects content from its own and from CTAT activities
- GIFT could affect CTAT behavior by, e.g., specifying skills of interest, mastery thresholds
- CTAT skill values could drive GIFT expertise assessments

Discussion and Outlook

- By integrating GIFT/CTAT/edX, we are creating a MOOC that synergistically combines:

  - GIFT EMAP adaptive outer-loop control for all activities except course discussion forum

  - CTAT adaptive outer loop control and adaptive inner loop functionality, to support multi-step problem-solving activities

- Our project will provide a practical framework for adaptivity in MOOCs, supported by proven authoring tools

Accomplishments

- Initial integration in which GIFT and CTAT activities are embedded separately into edX

- Made GIFT an LTI Provider

- Start bringing BDEMOOC content into GIFT, start creating content for all four EMAP quadrants

Future Work

- For GIFT-EMAP control over CTAT tutors, further extend GIFT to implement the LTI Consumer protocol.

- Enable GIFT to affect CTAT behavior by setting parameters when it invokes CTAT: mastery thresholds, maximum problem counts, etc.

- Bring more content into GIFT.

Thank You

- Questions?

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- Time for a break!

Comparing CTAT & GIFT student models

Possible Example of Long-term Vision
How would we like it to work?

- Student in the BDEMOOC reports interest in clustering, factor analysis, and bottom-up methods (key topics in educational data mining)

- In week 2 of the course, GIFT adapts to student interest to guide student to topic of interest (clustering), rather than the default path through the course (in which the week 2 topic is prediction models)

- In GIFT recall activities, student successfully demonstrates mastery of key facts and concepts around clustering

- Student starts the clustering CTAT assignment with RapidMiner but skips over the videos on procedures for clustering

- Student struggles with the first CTAT assignment on clustering, specifically with respect to selecting how many clusters to use.

- With data from CTAT, GIFT adaptively recommends that the student watch the video on how to select the number of clusters (it recognizes that the student needs remedial support but has covered the facts and concepts)