

Introduction

- Intelligent tutor systems (ITS) are effective for improving students' learning outcomes
- These systems provide students with personalized hints, practice problems, and feedback
- Despite these benefits, ITS have been difficult to produce at scale because they require programming expertise and substantial development time
- We propose the use of teachable AI and machine teaching technology to support efficient authoring of new ITS content at scale

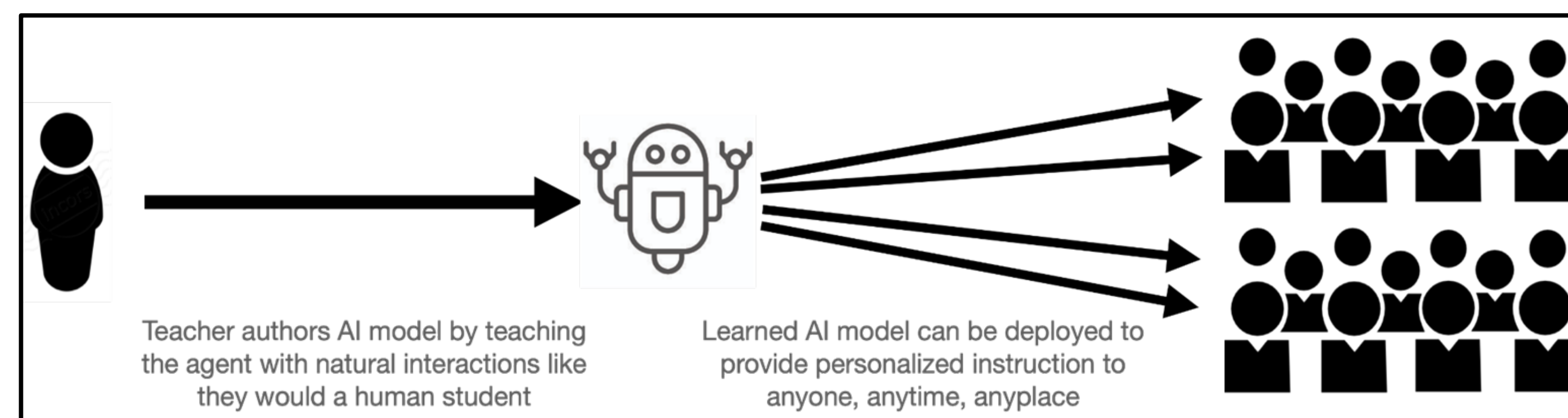


Figure 1. Apprentice Technology will let Teachers Create Tutors by Teaching an Agent

The Apprentice Vision

- We envision creating teachable agents that let teachers naturally author new ITS content without programming
- Our final Apprentice system will let teachers:
 - Create tutor interfaces via a simple web-based, drag-and-drop builder
 - Author the cognitive model to power the tutor by teaching an agent directly in an interface using examples, feedback, and verbal instructions
 - Deploy tutors to their class via their LMS platform (e.g., BlackBoard/Canvas) with just a few clicks
 - Track/visualize student performance and learning
- Our goal is to create a system that is as simple to use as Google™ forms, but lets teachers create pedagogically effective ITS at scale

Apprentice Tutor Platform

- As a first step, we have created the Apprentice Tutor platform: <https://tutor.apprentice.ai>
- This system supports the Learning Tools Interoperability (LTI) protocol, so it can be easily integrated within popular LMS systems, such as BlackBoard, Canvas, and Piazza
- Each tutor leverages a rule-based AI model to trace student's problem solving and provide contextualized hints and feedback
- Each tutor also leverages Bayesian Knowledge Tracing to track what students know and do not know and to provide personalized next problem recommendation
- Every student transaction is logged, so that we can provide teachers/student with estimates of learning
- System can export anonymous data for sharing across the NSF AI-ALOE institute

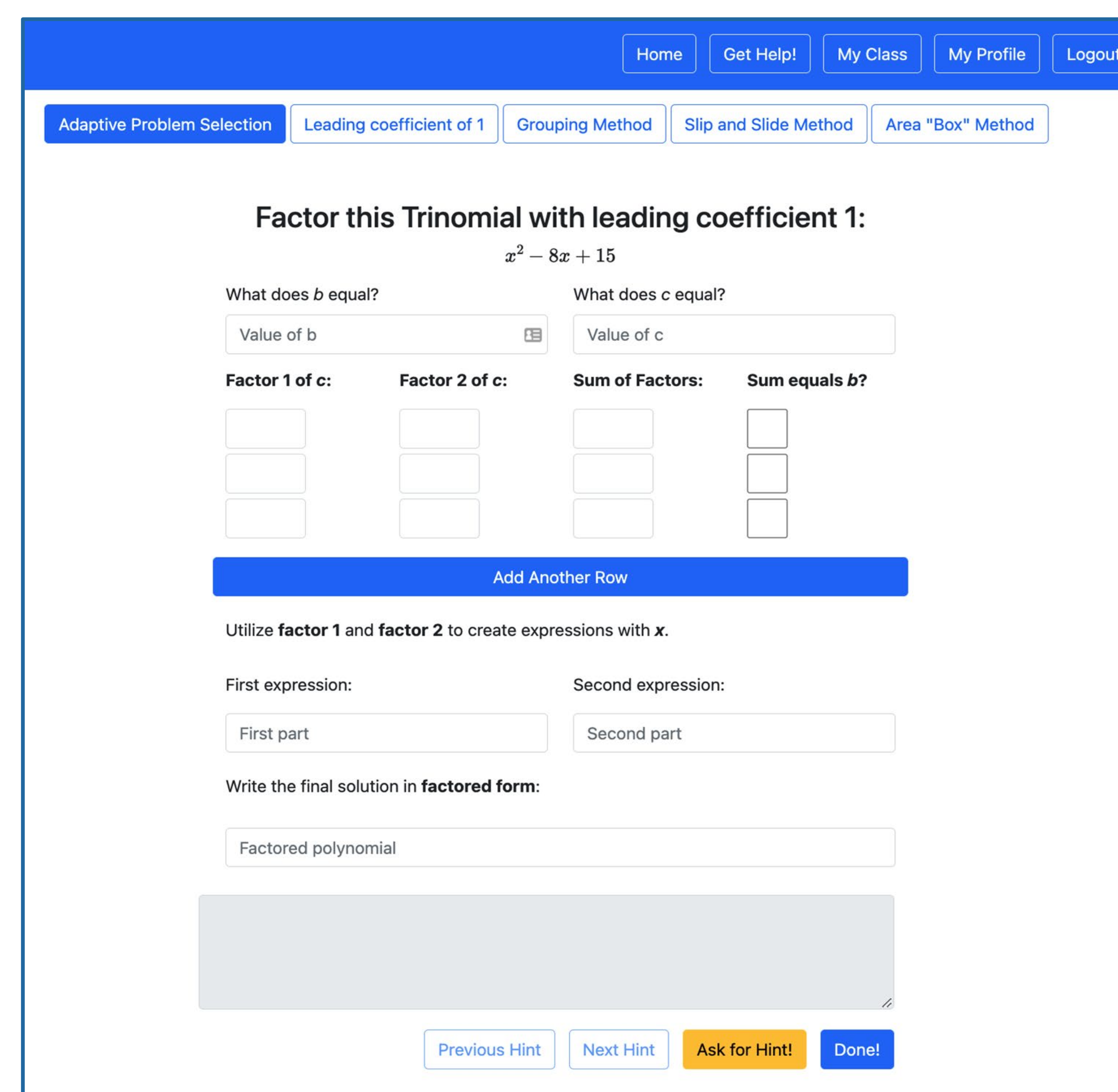


Figure 2. Polynomial Factoring Tutor for MATH 1111 (TCSG)

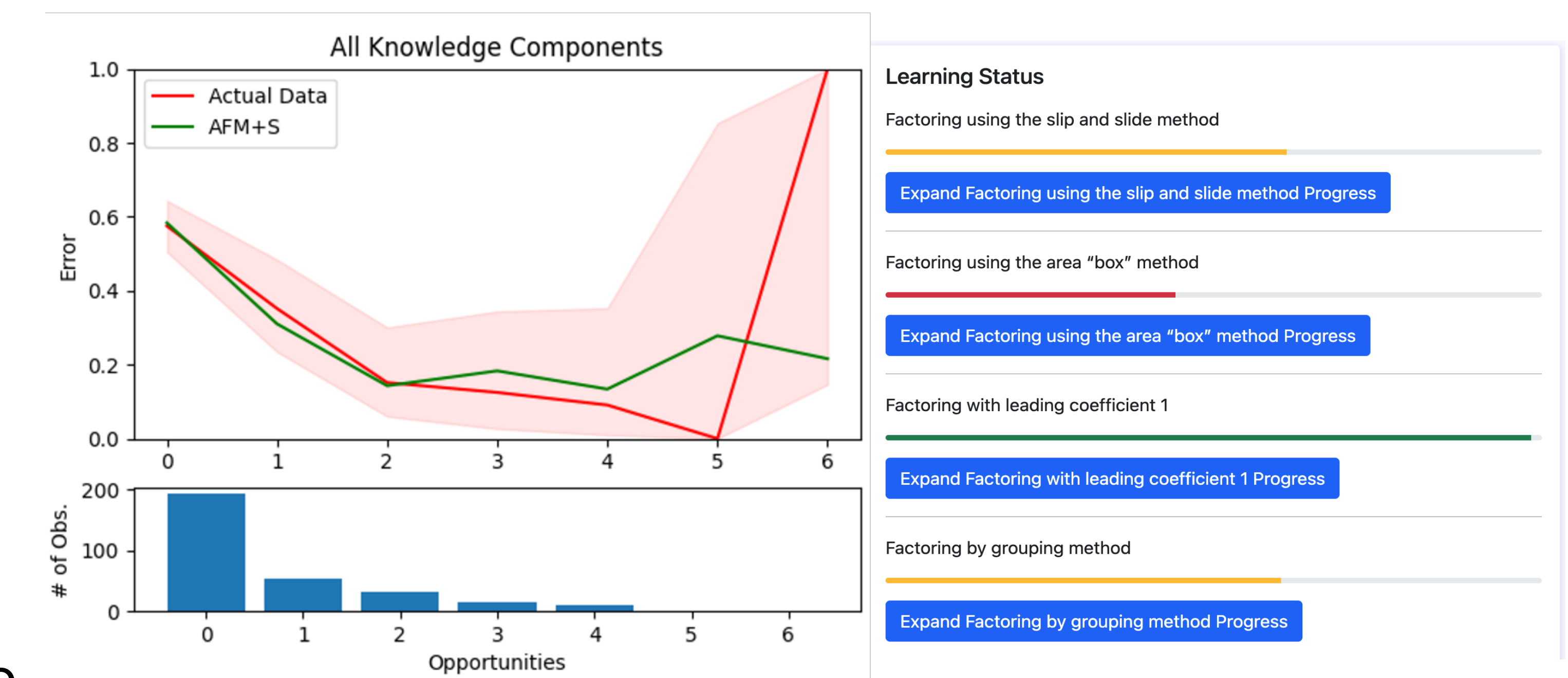


Figure 3. Tutor Learning Curve (left) and Student Skill Dashboard with Mastery Estimates (right)

Preliminary Deployment

- For cycle 1, our research team manually created a polynomial factoring tutor for TCSG's MATH 1111 course (college algebra, see Figure 2)
- This technology was deployed to support one instructor with three class sections; the tutor was provided as optional, supplemental support
- During our deployment, 22 students used our tutor to produce 892 transactions
- The average student performed 40 steps within the tutor (std=83.5; min=1; max=357)
- A learning curve analysis of this tutor data shows preliminary evidence for learning (see Figure 3)

Discussion & Future Work

- We are currently manually constructing a second MATH 1111 tutor to teach exponent rules
- For cycle 2, we will deploy our factoring and exponent tutors to 265 students across 30 sections
- We have started initial development of our Apprentice agents that will support tutor authoring via teaching
- We have started exploring novel ways to visualize data from Apprentice tutors to support the needs of stakeholders (students/teachers/administrators)