Piloting Intelligent Tutoring Systems to Enhance Sectoral Training Programs

EARLY FINDINGS AND LESSONS LEARNED

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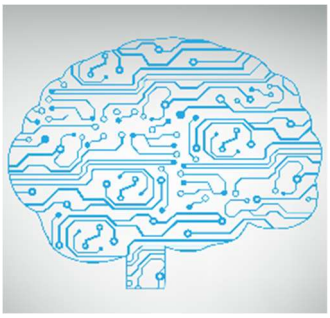
PILOT SNAPSHOT



About Intelligent Tutoring Systems

Intelligent tutoring systems, or ITS, are adaptive computer-based learning environments. They combine our knowledge of how people learn with cutting-edge behavioral, psychological, linguistic, emotional, and computational models. ITS track behaviors and inputs to measure learners' knowledge, engagement, and growth, and then use these data to create personalized learning opportunities.

What Is the Learning Partnership and What Have We Done to Date?

Partnership. Per Scholas, the American Institutes for Research (AIR), and the University of Memphis collaborated on an ITS pilot project under AIR's PROMISE Center.

Goal. This project explores ITS as a mechanism for helping sectoral training programs improve outcomes for learners. The first phase of the partnership was designed to establish proof-of-concept by conducting a pilot to assess the feasibility and efficiency of building an ITS for one of Per Scholas' most popular courses. This report summarizes what we accomplished and learned during this first phase.

Importance. Workers are beginning to disconnect from the labor force at high rates due, in part, to rapidly evolving skill requirements. Finding effective ways to help adult workers upskill and reskill to work in high-demand sectors is vital for economic prosperity.

Pilot design. We developed three prototype modules to provide Per Scholas learners with tutoring on complex information technology (IT) scenarios and concepts. We then tested the prototype with Per Scholas learners and applied what we learned about question development efficiencies and the perceived usefulness and usability of ITS features.

Measurement. We conducted interviews and tested developed questions with instructors and learners to understand learner needs and motivations, identify the study resources learners currently use, and get feedback on ITS content, features, and accessibility.

What Have We Learned So Far?

- Feedback from instructors and users indicates that these populations found the ITS to be of great value when interacting with the prototype we developed. They also identified specific features they found beneficial and areas for improvement.
- Per Scholas managers shared that ITS similar to the prototypes we developed would be useful for additional courses and would be feasible to scale up given their experiences with development.
- ITS development can be done efficiently in partnership with program subject matter experts (SMEs), if you assemble the right team and develop clear goals and work plans.
- It is possible, even in a pilot, to create templates and workflows that can be adapted to future contexts and help reduce burden when scaling ITS.

What's Next?

- Use the lessons learned from Phase 1 as we build out the ITS for the full curriculum in Phase 2.
- Implement rigorous research designs to test the efficacy, usability, and actual usage of the ITS.

1. Introduction

Helping underserved workers efficiently learn new skills matched to labor market needs is vital to improving the quality of workers' lives and to promote equity in the larger economy. Employment opportunities that offer family-sustaining wages have been in decline for years for adults without college degrees (Groshen & Holzer, 2021), closing off pathways to advancement and removing otherwise talented workers from the labor market. Rapidly evolving technologies and their impact on the world of work mean that workers need to update existing skills or acquire new ones regularly. Unfortunately, workers without degrees looking to upskill or reskill face many barriers, including the high costs of college or training programs, a lack of childcare, and transportation difficulties, to name only a few (Schaffhauser, 2020; Williams et al., 2022).

Unsurprisingly, these barriers to obtaining new skills exclude many workers from the labor market. In 2023, the U.S. Chamber of Commerce reported that there are nearly 3 million fewer Americans in the workforce compared with February 2020. This has fueled a labor crisis as the number of job openings far exceeds the number of unemployed people (Ferguson, 2023). Employers also face rising shortages in the supply of skilled workers, making it harder to compete in the global market (Ghayad, 2023). Without robust efforts to improve access to effective skills training and job placement programs, the rising gap in economic opportunity is likely to widen.

Despite this rising gap, there are a few landmark programs that are providing rapid skills training and connecting thousands of vulnerable or unemployed workers with high-quality jobs in high-growth sectors within local communities. Programs such as Per Scholas, Year Up, and Project Quest have produced lasting positive impacts on participants' employment and earnings (Katz et al., 2022). Historically, these programs achieve success by combining skill-based training with in-person mentorship and direct pipelines to local employers, creating opportunities for participants to thrive in place. However, implementing these models is resource intensive for program administrators and requires highly knowledgeable staff, which limits the replicability and scalability of these programs.

How might we strengthen and scale these promising models to serve the millions who need their services?

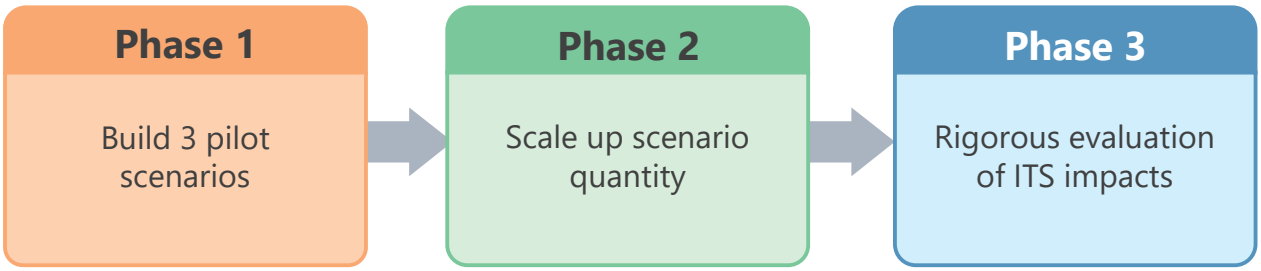
Under AIR's PROMISE Center and with funding from its Equity Initiative, AIR, in partnership with Per Scholas and the University of Memphis, embarked on a project to leverage technology and machine learning to strengthen program implementation, improve outcomes for learners, and help program administrators work more efficiently. Per Scholas is a sectoral training program

that provides adult learners underrepresented in technology with an opportunity to quickly reskill into the desirable field of IT by obtaining industry-standard certifications. In response to the COVID-19 pandemic, Per Scholas—like countless other training providers—pivoted from in-person courses to virtual and asynchronous learning to continue providing access to much-needed training. This flexible mode of delivery provides new opportunities for leveraging technology and serving populations that were previously underserved due to geography, lack of childcare or elder care, or conflicting work responsibilities.

AIR and the University of Memphis explored the use of ITS as a mechanism for helping programs scale. ITS are adaptive software that provides immediate and personalized instruction and feedback to learners without requiring synchronous (or even asynchronous) inputs from a human teacher. ITS offer promising and low-cost ways to supplement live instruction, making it more cost-effective to assist learners who need more intensive, personalized support. It may also free up instructors, which in turn provides more time to directly support learners and potentially increase the number of learners in a class.

Through this partnership, we plan to conduct a three-phase project (see Exhibit 1). We recently completed Phase 1, where we established a proof-of-concept ITS pilot for one of Per Scholas' most in-demand courses, IT Support. This report presents an overview of our project, including its goals, focus, and design (the remainder of section 1); an overview of what we accomplished in Phase 1 and lessons learned so far (section 2); findings and identified areas for improvement (section 3); and a summary of lessons learned and a preview of what is next (section 4).

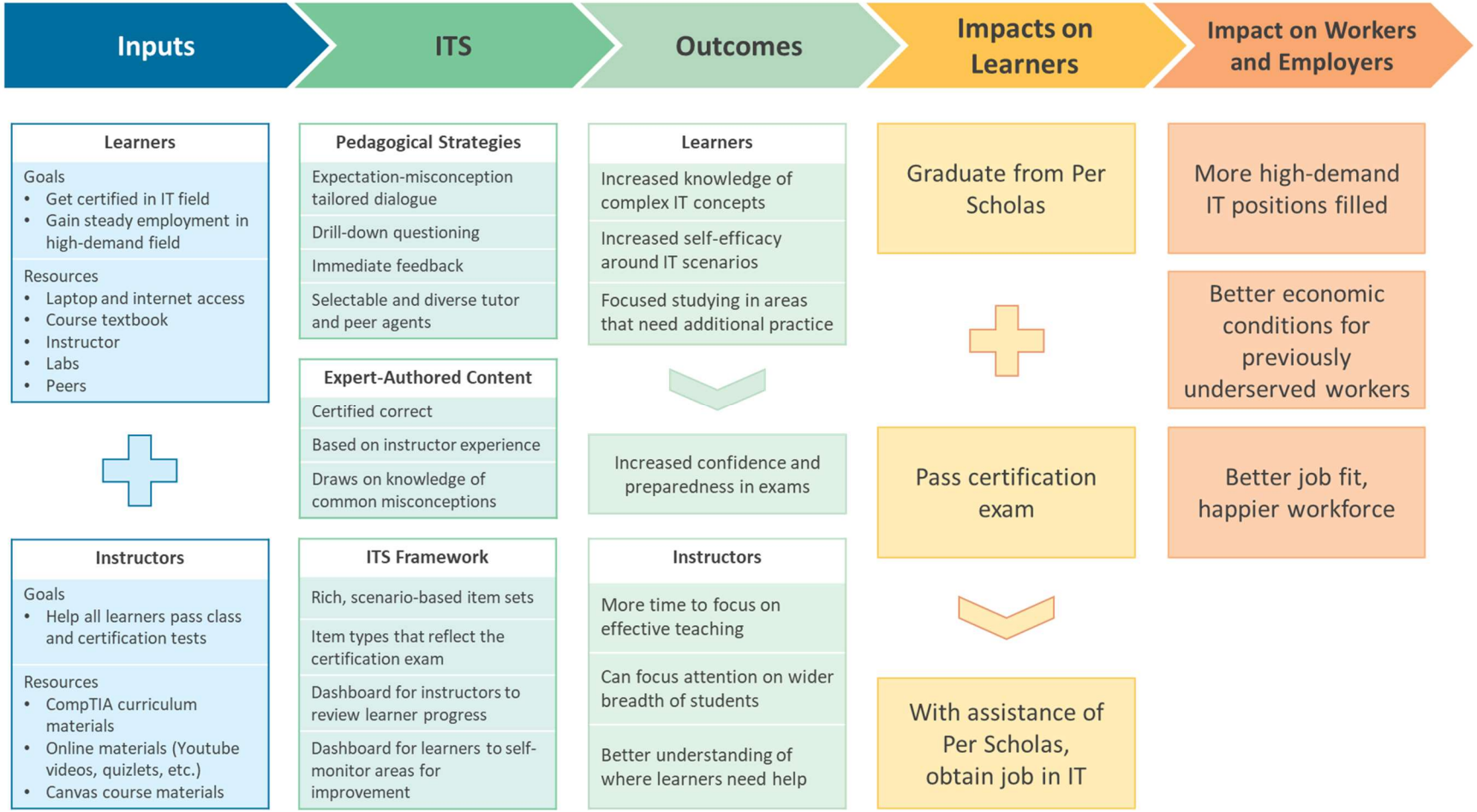
Exhibit 1. Phases of ITS Project



Project Overview

By building an ITS for Per Scholas, AIR and the University of Memphis want to learn whether this type of support can increase the reach, scale, and impact of a proven sectoral training program. The partnership will examine whether developing and integrating an ITS into Per Scholas' courses improves the certification rate for learners by providing them with a safe environment to test their knowledge, refamiliarize themselves with prior lessons, or catch up due to class absences. Exhibit 2 outlines our theory of change with expected outcomes and impacts.

Exhibit 2. Theory of Change



The research questions that guide this effort are as follows:

1. **Feasibility:** Is it possible to develop relevant and useful ITS content efficiently for existing Per Scholas courses? Can typical ITS frameworks be adapted to scaffold learning for sectoral training programs?
2. **Viability:** Are the time, effort, and processes needed to create the solution modest enough that they can be replicated and scaled? Can we successfully establish content authoring processes that can be readily adopted by sectoral training program staff in the future?
3. **Desirability:** Is the prototype we are developing useful for learners and instructors? What improvements does it need to meet learner needs? What optimization and intensification of the ITS needs to occur to improve learner experiences?
4. **Scale-up:** What does it take to build out ITS for an entire course and integrate it seamlessly into the online learning environment? What adjustments may be necessary for different contexts of instruction?
5. **Impacts:** To what degree does the integration of ITS improve learning in class (grades, test scores)? To what degree does the integration of ITS improve certification rates?

To address these research questions, we have designed a three-phase effort:

- **Phase 1 (April 2022–January 2023):** We built a prototype ITS on three distinct topics covered in the ITS Support course offered by Per Scholas. The goal of Phase 1 was to test the feasibility of developing such a system and assess the level of effort and the processes needed to do so. In this effort, current and former Per Scholas instructors worked with AIR and engineers from the University of Memphis to develop content, advise on item formats, and give input on the interaction flow for the ITS. We then conducted initial usability tests on the prototype with learners and instructors to gain insights on how to improve the system. During this phase, we addressed research questions 1–4.
- **Phase 2 (April 2023–October 2023):** We plan to build out a suite of scenario-based questions covering the most pressing topics needed to help learners pass their certification exam and gain skills needed for success in future employment. At the end of this phase, we will fully integrate the ITS into the course, making it available for all enrolled learners. We will also conduct small-scale user tests of the ITS to gather initial evidence of efficacy.
- **Phase 3 (TBD):** We will rigorously test the ITS, rolling it out in select course sections to compare outcomes between learners with and without access to the system. We will study its uptake, impacts on learners such as their certification rates, and instructor experiences. During this phase, we plan to address research question 5.

In the remainder of this chapter, we provide more detail on why we focused on ITS as the technology to leverage for this opportunity and why we think Per Scholas is a promising program for such a technology.

What Are ITS and What Is Their Promise for Sectoral Training?

At their core, ITS are programs or apps that help learners master new concepts by providing personalized feedback and guidance through a computer tutor. The "tutors" in an ITS fall into distinct categories. Some tutors may act as invisible learning managers that select the problems and questions the learner works on. In other systems, tutors may appear as avatars that communicate directly with learners, mirroring a more typical, conversational tutoring experience. What sets intelligent tutors apart from other kinds of educational technology is how they adapt to the learner. The tutoring system takes the inputs from the learner and builds a model of what it thinks the learner already knows and what they have yet to master. This information can help inform targeted instruction, focused studying, and additional activities to improve comprehension.

Since the 1960s, we have seen examples of ITS in K–12 education, the military, and some employee training contexts. Although ITS are not yet widespread in workforce contexts, these systems are beginning to gain traction as artificial intelligence (AI) technology becomes more mainstream. This traction is particularly exciting as extensive research in the ITS space has shown an immense potential for rapid learning gains that are on par with or better than those seen with human tutors (Exhibit 3).

ITS offer certain advantages that may be particularly well suited to the adult training environment. For example, unlike traditional tutoring, an ITS can readily serve thousands of learners at once and may be more affordable and feasible for large programs. Our ITS, discussed in the following chapters, has a cost

Exhibit 3. Why ITS?

ITS have been subjected to years of rigorous research by university scientists and industry researchers. Literature reviews and meta-analyses have shown the average learning impact for an ITS, tested with secondary or postsecondary students, to have an effect size of d = 0.40 - 0.80 (Kulik & Fletcher, 2016; Ma et al., 2014; Steenbergen-Hu & Cooper, 2013, 2014; VanLehn, 2011; Xu et al., 2019), putting them nearly on par with human tutors (VanLehn, 2011).

Researchers have also broken down the parts of an ITS to understand their individual contributions to learning. For example, conversational agents (Baker et al., 2006), immediate feedback (El Saadawi et al., 2010; Kehrer et al., 2013), and scaffolding (Razzaq & Heffernan, 2006) are ITS components that have been shown to have a positive effect on learning.

of roughly $0.90 per scenario-based question per user, regardless of how often the learner revisits the ITS. Because ITS do not require a human instructor, learners can access the questions whenever they need to, offering a time-flexible solution to busy adults. This feature may be especially important for learners at Per Scholas, who may have responsibilities such as childcare or existing employment while engaged in the program.

In summary, we focused on developing ITS for Per Scholas for three reasons:

- ✓ ITS are cost-effective options for learners who need help studying, with proven impacts on learning.
- ✓ ITS can be especially beneficial for serving adult workers with diverse needs.
- ✓ ITS offer unique opportunities to transfer their innovations to workforce programs, where ITS are currently underused.

Why Focus on the Per Scholas Program for This Effort?

Per Scholas provides no-cost career and skills training to help adult learners build careers in the high-demand, high-growth, and high-wage IT sector. Per Scholas offers training programs that lead to multiple credentials in the IT sector, including IT support, cybersecurity, data engineering, software engineering, and cloud capability. AIR's PROMISE Center partnered with Per Scholas because the Per Scholas program:

- ✓ Has an effective model with proven impacts that merits scale-up
- ✓ Focuses on advancing equity and serving high-need populations in localities where access to opportunities is segregated by race and place
- ✓ Offers supports that tackle multiple barriers to opportunity
- ✓ Has a commitment to learning and data-driven decisions that advance the field
- ✓ Is expanding in ways that offer unique learning opportunities

Exhibit 4 provides further context on the Per Scholas program, its goals, design, impacts, and the features that make it a great fit for a learning partnership.

Exhibit 4. Why Per Scholas?

- **Per Scholas has an effective model that merits scale-up.** In 2021, the program helped nearly 2,000 graduates find jobs with wages that were three times higher than the wages participants received before the program, on average. A long-term, randomized controlled trial by WorkAdvance showed that an enhanced version of the Per Scholas program significantly increased the average earnings for those enrolled in the program (Shaberg & Greenberg, 2020).
- **The program is focused on advancing equity.** Per Scholas seeks to give opportunities to people who are typically underserved by traditional education systems and underrepresented in the field of technology. According to course data for Per Scholas from 2021, 83% of the learners enrolled in one of their most popular courses identified as a person of color, 34% of their learners were women, and 45% were born outside of the United States. Roughly half of their learners held a high school diploma as their highest degree. The Per Scholas program focuses on eliminating race- and place-based barriers for learning by serving diverse learners in cities across the United States.
- **The program offers supports that tackle multiple barriers to opportunity.** Enrollment in a Per Scholas course is free for learners, including the cost of the certification exams. One of their most popular classes, IT Support, lasts only 12 weeks, making it more accessible for adults who cannot wait 2–4 years to complete a formal degree. Per Scholas knows that getting into a new career is not just about certifications or degrees. Per Scholas provides learners with hands-on career-readiness services and job placement assistance. Support services may also include, but are not limited to, training, coaching, and other wraparound services (Hendra et al., 2016). Per Scholas has strong relationships with several local employers to help place learners after training.
- **Per Scholas is committed to learning and data-driven decisions.** Per Scholas carefully tracks its learner's outcomes, including certification exam pass rates, how quickly graduates enter the workforce, and graduates' hourly wages. This information allows Per Scholas to monitor the efficacy of its services and identify areas for improvement. Per Scholas has also participated in multiple rigorous, multi-year studies to determine the impacts of its program, highlighting the organization's dedication to understanding the true impact of its program.
- **Per Scholas is expanding in ways that offer unique learning opportunities.** Per Scholas is in a growth phase and has aggressive plans to serve additional learners each year. This growth phase offers an opportunity to understand how sectoral programs grow and the pains they may experience along the way, as well as the solutions to those growing pains.

2. Pilot Phase Accomplishments and Key Components

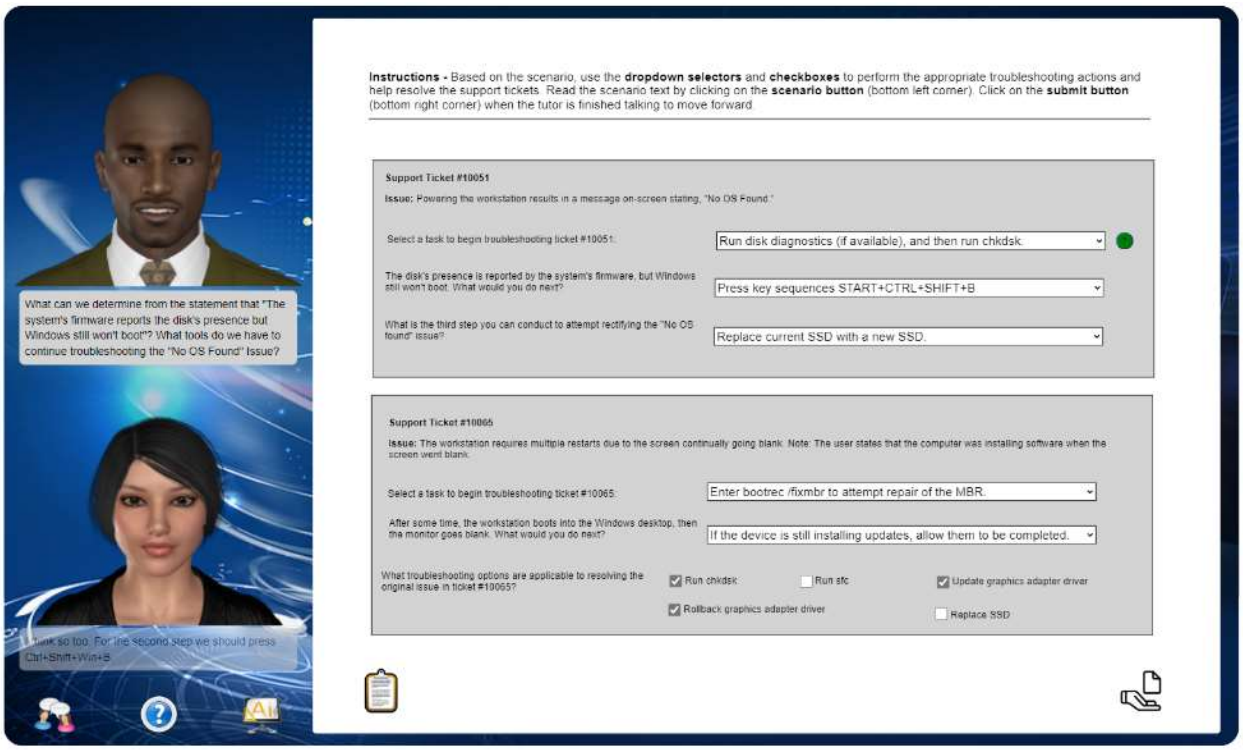
Our goal in Phase 1 was to understand the feasibility, desirability, and viability of integrating ITS into the Per Scholas program. We began by creating a minimum viable product in Phase 1, which allowed us to explore the process of development. In this chapter, we describe the work completed under this phase and the features of the ITS we developed. We also detail the key steps, critical design decisions, and lessons learned for those interested in piloting ITS in their own context.

Overview of ITS

Together, AIR and Per Scholas decided to develop and user test a proof-of-concept ITS for Per Scholas' most popular entry-level course, IT Support. The IT Support course prepares learners for CompTIA A+ certification, which is earned by passing a set of two exams. This certification, which is the industry standard qualification for a career in IT, may lead to employment and competitive earnings (Coursera, 2022). As such, IT Support is one of Per Scholas' most popular courses, with approximately 1,350 learners enrolled in 2021. Per Scholas shared that its learners typically find the scenario-based questions that draw on concepts taught across multiple lessons to be one of the biggest barriers to passing the exams. Learners typically respond to five or six of these questions on each test, making them particularly critical to a learner's ability to achieve certification. With the help of Per Scholas staff and instructors, we designed and developed an ITS to guide learners through three such scenario-based questions.

The ITS has several features and design considerations that were tailored to Per Scholas. For example, we modeled each scenario-based question after the types of questions that appear on the CompTIA A+ exam to familiarize learners with the exam's components (e.g., scenario language, question style, etc.). The two tutor agents appear at the side of each problem. One agent serves as the tutor, providing feedback, explanations, and hints (see Exhibit 5). The other agent, the "student agent," acts as a fellow learner, agreeing with the learner when they answer items incorrectly. This dynamic is designed to improve the emotional experience of receiving corrective feedback. Having the tutor agent deliver clear feedback to the student agent instead of directly to the learner can create a more supportive learning environment.

Exhibit 5. Snapshot of ITS Prototype



We included several distinct features to advance key ITS goals:

- **Fostering persistence:** The ITS gives learners multiple chances to answer each item and the tutor gives tailored hints when items are answered incorrectly. After the tutor reaches the set number of hints, if the learner is still not getting the correct answer, then the learner is shown the correct response.
- **Detailed explanations:** After the learner answers the item correctly or is shown the correct answer because they exhausted the set number of clicks, they get a pop-up with buttons next to each item response option. By clicking on the button next to each item, they can explore additional in-depth explanations that help reinforce why an answer is right or wrong.
- **Accessibility:** The system also provides multiple accessibility supports, such as agents speaking aloud with captions, a transcript that can be accessed at any time, and a button that directs students to additional resources in case learners want to review course materials before proceeding further.

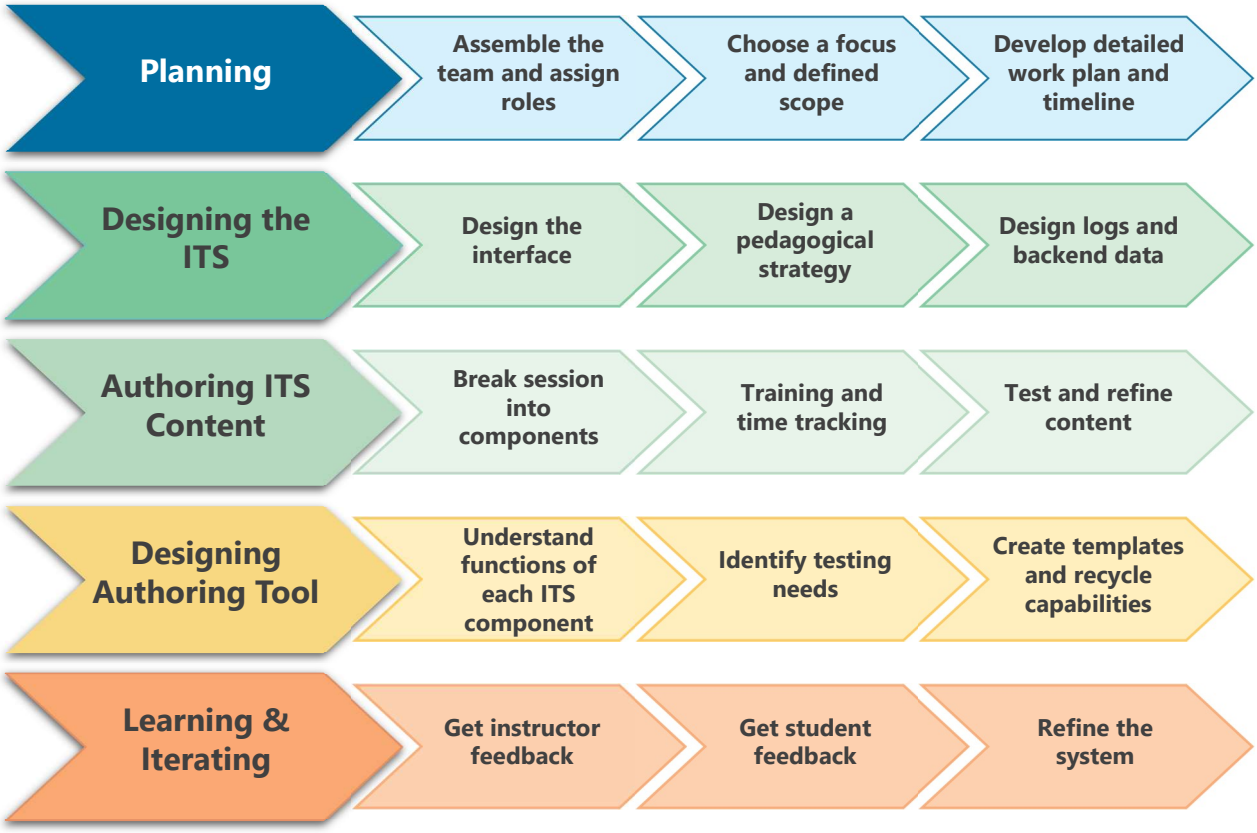
Appendix A provided an in-depth walk-through of the ITS features and tutorial flow. Appendix B shows the user testing protocol we used to get feedback. Appendix C details future revisions,

including additional accessibility features, based on user testing and feedback (see section 3 for an overview of our user testing).

Key Steps for Feasible and Viable ITS Integration

AIR, Per Scholas, and the University of Memphis worked closely to complete an ambitious scope of work in a short period of time (9 months). We organized the work into five key steps (Exhibit 6). Note that these steps are not linear; we conducted many of these steps concurrently.

Exhibit 6. Key Steps and Substeps in Phase 1



In the section that follows, we discuss our approach to each of these five steps of prototype creation and testing, as well as the substeps we took to make each step successful. Our team's hope is that the lessons we learned will help inform considerations for others embarking on similar work.

Step 1: Planning

Development projects hinge on their planning. Assembling the right team, defining a clear scope and focus, and following a timeline creates the groundwork for a successful project, particularly if the project is relatively novel.

***Assemble the right team and assign complementary roles*:** Having the right team is critical to the success of any project, but never more so than in development work. We had three major teams, each with its own expertise (see Exhibit 7):

- **AIR** served as the lead project design and research team, bringing expertise in workforce and sectoral training programs; pilot design, development, execution, and evaluation; translating ITS concepts and operations for practitioners; and managing multi-functional teams. The AIR team played leading roles in creating scenario text and summaries (Steps 1 and 5; see Exhibit 7) and supported and managed all remaining tasks.
- The **Per Scholas** team, which included managers and instructors, brought context and subject matter expertise in program operations, course content, and insights regarding learner and instructor needs. The Per Scholas team contributed substantively to defining the project focus and scope (Step 1), authoring ITS content (Step 3), and providing feedback in learning and iterating (Step 5).
- The **University of Memphis** served as the engineering team and brought extensive experience in building, modifying, and researching ITS in varied contexts. Memphis led the team in designing the ITS (Step 2) and designing the authoring tool (Step 4) and collaborated with AIR and Per Scholas to oversee Step 3, authoring ITS content.

Exhibit 7. Distribution of Roles for Phase 1 Steps

Steps	AIR	University of Memphis	Per Scholas
Step 1: Planning	Lead		
Step 2: Designing the ITS		Lead	
Step 3: Authoring ITS Content			Lead
Step 4: Designing Authoring Tool		Lead	
Step 5: Learning & Iterating	Lead		

Select a course focus, content focus, and tightly defined scope: We focused on Per Scholas' entry-level course, IT Support, and narrowed our prototype to three topics. We selected these scenarios based on our priorities for this phase: building out scenarios with diverse question types that focus on difficult topics for learners. The selected scenarios allowed us to get a sense of how to approach the types of questions asked on the exam (e.g., multi-select, drag-and-

drop), how interactions should play out, and what kind of time commitment it took from the team to create a full scenario question. Although all three partners were excited about all the directions we could take the ITS, grounding our work in the scenario-based questions gave us a starting place for our design.

Develop an ambitious but realistic work plan and timeline: Because Phase 1 involved exploring new processes and ways of collaborating across partners, creating a detailed work plan and setting well-defined milestones for our work was critical. We began by dividing our work into key steps and substeps and creating a week-by-week timeline of what we wanted to accomplish, including when to receive materials from Per Scholas, decide on topics, create a prototype of the system, begin training SMEs on content creation, finish our first scenario, and begin user testing sessions. Each week, we planned at least one minor milestone, with major milestones occurring one to two times a month. The work plan showed clearly which partner was responsible for which milestone. Sharing this work plan across partners and working together to revisit and revise the work plan regularly proved useful for (a) setting expectations for the level of effort for each partner, (b) showing interdependencies between tasks, and (c) identifying risks to the timeline. To maintain the pace on our ambitious timeline, we set up regular meetings with different subteams.

> ***Lesson Learned***
>
> Select topic areas early—it is impossible to get started without them, and delays can push back the timeline before the real work gets underway!

Planning Takeaways

- ✓ Partner with the right people, and assign roles based on their strengths. Several subteams may be needed to accomplish the work.
- ✓ Narrow down the focus of the partnership as quickly as possible so that actual work can begin. Before doing so, meet with all relevant stakeholders about high-leverage areas.
- ✓ Plan ambitiously but remember to regularly revise the work plan as new information becomes available.

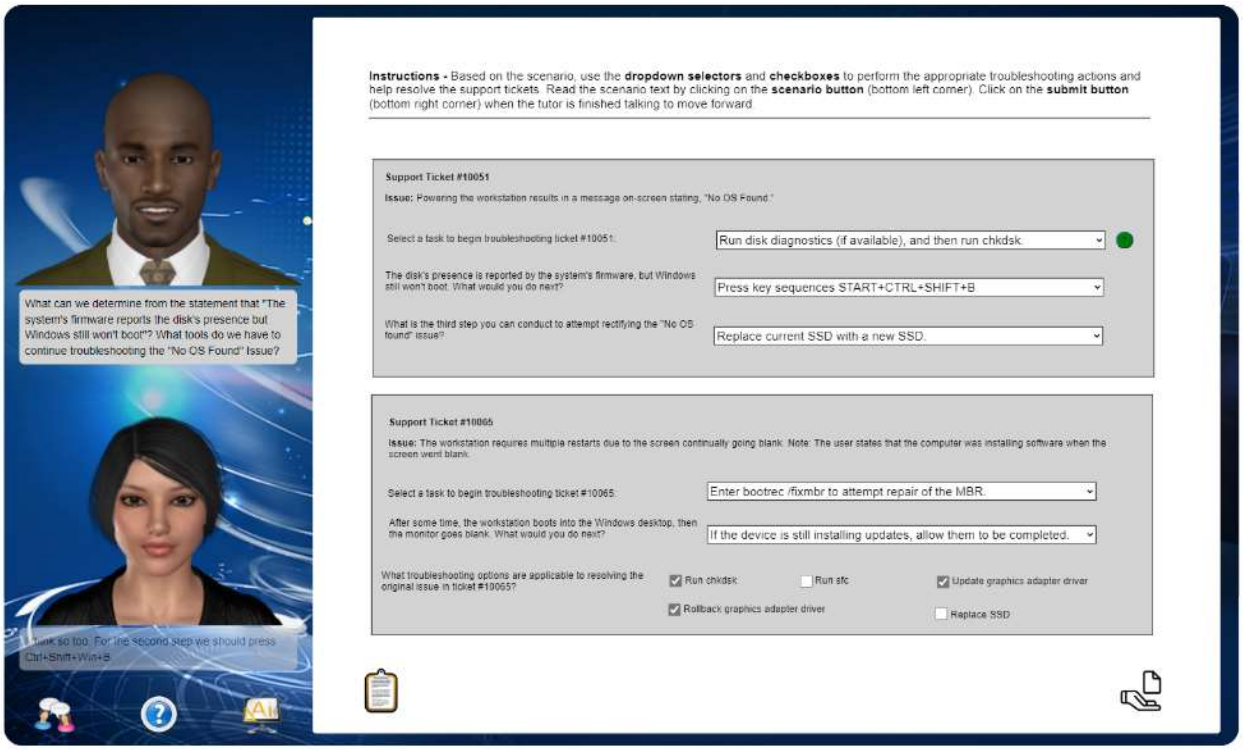
Step 2: Designing the Tutoring Environment

Teams must make several design decisions for every facet of the tutoring environment—including functionalities, aesthetics/layout, interactions, and pedagogical designs—all of which must work together to create an optimized user experience.

Design the interface: Our primary goal for this ITS was to give learners the experiences they need to feel comfortable, confident, and knowledgeable as they go into their exams. To accomplish this goal, we decided to construct an ITS that resembles the exam environment in

terms of its layout and features, such as having the scenario text as a panel that could be hidden shown with a toggle. However, we also wanted to maintain the personable and supportive feel of one-to-one tutoring. To balance these goals, we included tutor and student conversational agents (discussed next) and accessibility options not available in the exam environment (see Exhibit 8).

Exhibit 8. Example Scenario Problem Styled After the Exam with Drop-Down and Check-All-That-Apply Question Styles



Design a pedagogical strategy: Arguably the most important step in building a tutoring system is designing a pedagogical, learning-focused strategy that addresses the problems learners experience when studying. For our project, we learned through discussions with Per Scholas managers and instructors that learners struggled with answering complex scenario-based questions that target different knowledge components and include multiple subquestions. They had limited access to effective practice questions that offered explanations on why the response to each question is right or wrong. As a result, they ultimately either rely on instructors for assistance or go without assistance – derailing their success. To remedy this, we considered the following questions, which framed our pedagogical approach:

- **Do we want conversational agents?** Research shows that conversational agents may have advantages for learning (Baker et al., 2006). For this ITS, we chose to have two

conversational agents—a tutor and a student—to allow for more conversational options and to give the system the feel of a classic tutoring session.

- **What do we want to happen when learners get a question wrong (or right)?** Receiving clear, immediate feedback helps learners identify areas that need improvement (El Saadawi et al., 2010; Kehrer et al., 2013). Given that our ITS is a practice tool, learners may attempt each subitem multiple times, with tutors providing direct feedback, explanations, and hints to help learners arrive at and understand the correct answer.
- **How can learners review information at the end of the problem?** We included summary buttons after each item that further elaborate on the quick explanations given by the tutor. We also included visual cues to help learners track their progress. Green and yellow buttons on each item indicate correct or incorrect attempts.
- **What resources and supports are available while they work on the problem?** Some learners may dive into a tutoring session before realizing they have insufficient knowledge to continue. To avoid having learners feel frustrated or give up, we included a support button that redirects learners to texts, labs, and other classroom resources on the topic that they can access without leaving the tutoring environment. When they are done reviewing these materials, they can immediately resume the tutoring.

The decisions associated with each question provided a starting point for our design and, importantly, could be tested empirically in future A/B experiments. We received feedback regarding some of these decisions in our user testing (see section 3).

Design logging and backend data: We built in data capture capabilities that allow us to reconstruct every learner and system action. Data, housed in the cloud, enable us to investigate interaction patterns, refine system behaviors, and understand learner experiences. These data also allow for the potential to integrate dashboard and reporting functionalities, which we plan to pursue in Phase 2.

Takeaways for Designing the ITS

- ✓ Let the primary goal drive the interface design, reducing the universe of decisions down to a manageable number.
- ✓ Consider how users will interact with the tutor and vice versa, optimizing for the specific context they are working within. Consult the literature to guide decisions and run A/B tests.
- ✓ Do not forget the data! It is easier to install data capture systems earlier in the building process than include them at the end.

Step 3: Authoring Content

The next step is to create the "meat" of the interaction—the content. Every scenario, question, and utterance of the agents must be generated by someone (or, as we move into a new age of generative AI, something). Because each element of the content of the ITS requires deep knowledge of the material and experience translating these concepts for learners, we asked three Per Scholas instructors to serve as SMEs for authoring the content.

Exhibit 9. Components of a Scenario-Based Question

We identified five major components that needed to be authored by SMEs.

1. **Scenario text:** Scenarios provide the context for the questions and often include critical details for consideration. Most scenarios ask learners to demonstrate knowledge across six or more different topics or skills.
2. **Questions:** Each scenario-based question asks the learner to respond to roughly 10 separate items, typically in the form of a check-all-that-apply or multiple-choice question.
3. **Feedback:** When a learner responds to an item, they need to know whether their choice was correct or incorrect and why. Immediate, just-in-time feedback is critical to a learner's metacognition (El Saadawi et al. 2010; Epstein et al., 2002) and to identifying misconceptions.
4. **Hints:** If the learner selects a wrong answer, we wanted the ITS to encourage them to try again by giving them additional information to consider, highlighting a key component of the question, or prompting them to recall something they learned in class. Currently, only one hint is authored per response item, giving the learner two opportunities to answer each item.
5. **Summaries:** As the learner and tutor move through the items, we wanted learners to have an opportunity to review detailed information about all covered items. This is a chance to address common misconceptions or provide additional information for curious learners.

Break scenarios into components: Once we understood how we wanted the ITS to behave, we broke each scenario-based question into its component pieces. We needed SME assistance to author each component piece. Exhibit 9 provides an overview of the five major components of scenario-based questions. We established guidelines, examples, and training materials for each component to help the SMEs produce high-quality content and dialogue.

Training and time tracking: Once we established the components, the University of Memphis and AIR teams trained SMEs from Per Scholas on how to author these. For this pilot effort, we used preexisting scenario-based questions and items from practice exams provided by Per Scholas to limit the authoring effort to feedback, hints, and summaries. The trainings stepped through the purpose of these components, gave examples of what they should look and sound

like, provided templates, and discussed some of the limitations of working with a text-to-speech voice that would speak the components aloud.

Having content experts serve as SMEs expedited the authoring process for us but we wanted to understand the costs for the SMEs for providing this support. We asked SMEs to track the time spent authoring and working with the team to understand the viability of scaling the ITS development beyond three scenario-based questions. The three SMEs each spent approximately three hours in training, and they spent an additional forty hours in total authoring content for the three scenario-based questions. (SMEs spent varying levels of effort given availability). This is significantly faster than expected given that this was their first experience with authoring. According to tutoring system developers at the University of Memphis, it typically takes trained and experienced staff 40 hours of authoring to develop 1 hour of tutored content (with our scenario-based questions taking approximately 15–20 minutes each). We hypothesize that SME's efficiency was due to their deep expertise, the well-defined and explained authoring tasks, rapid feedback, and access to on-demand technical assistance from ITS engineers. If the same individuals continue to serve as SMEs, we anticipate that authoring additional scenarios will be faster than is typical.

Test and refine content: During the initial authoring stage, we provided ongoing feedback and conducted office hours to help SMEs understand the appropriate level of detail needed. Following careful review, the team and SMEs revised authored content to express ideas clearly and succinctly. We plan to update the training materials for our new SMEs for Phase 2, drawing on lessons learned in Phase 1.

Takeaways for Authoring Content

- ✓ Identify all the different elements you need to write for each scenario and explain how they differ from each other.
- ✓ Train authors with illustrative examples and refined templates.
- ✓ Track time spent on authoring for each unit to better estimate how long full production will take. Continue to monitor time spent over time as these estimates can change.
- ✓ Be prepared to review and revise frequently! Authoring is an iterative process. Getting content right takes several attempts.

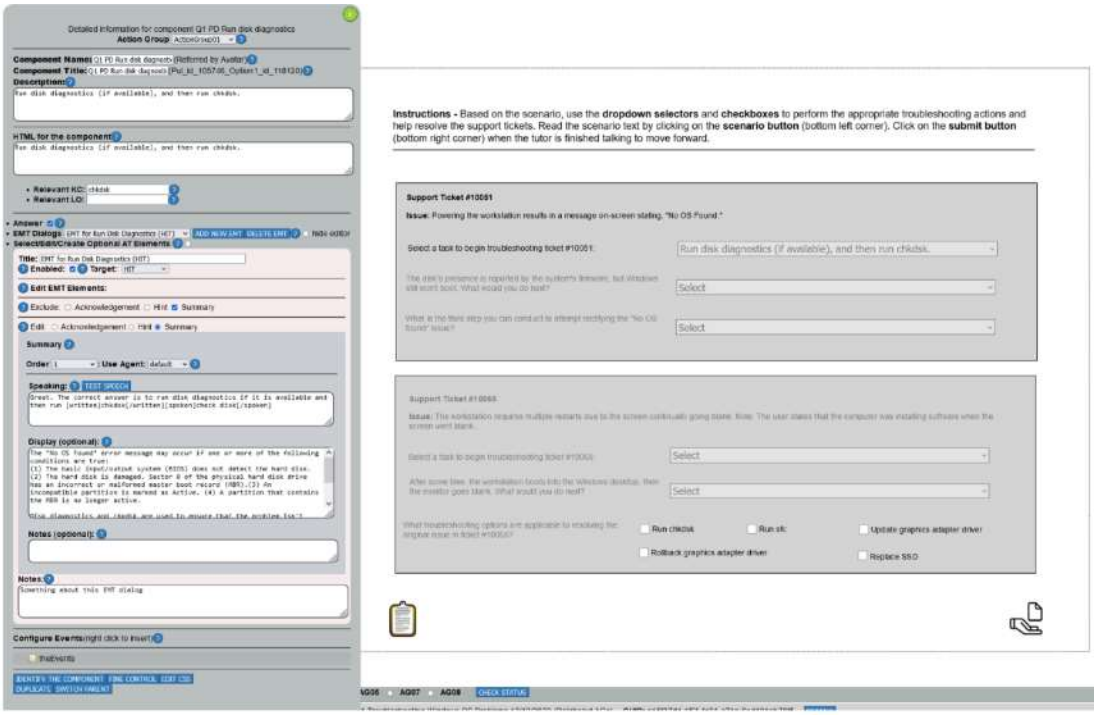
Step 4: Designing the Authoring Tool

Although it is possible to create tutoring interactions using the content developed in previous components, hand coding each question takes a significant amount of time and may generate inconsistencies across questions. To increase the scalability of our system both within Per

Scholas and to other programs, we created an "authoring tool" where content generated by SMEs is entered into an application that designs the tutoring interactions. Although this involves a significant investment of time up front, an authoring tool can reap significant cost savings when several scenarios need to be authored. This also lends sustainability to the system after initial production ends, as staff can update the cadre of scenarios as the exam and content evolves.

Understand functions of each ITS component: For each component authored by the SMEs, it is critical to understand exactly how that piece functions. For example, in our system, learners should first see the scenario text before anything else, agents should give negative feedback only when learners select a wrong answer, and summaries should appear after tutoring on that item finishes. We carefully documented the "triggers" for each component so that, once the text for a component is entered into the authoring tool, the tool knows exactly how to treat the text. In our system, components function consistently across questions.

Exhibit 10. Authoring Tool With Live Mockup and Entry Panel



Identify testing needs: We found it useful to test the scenarios before making them live. Our authoring tool allows authors to preview how entered text will sound[1] and behave. We were able to catch typos, identify errors in formatting, and improve dialogue. We were also able to

[1] Our tutoring system uses text-to-speech voices, which we recommend at least in the development phase of the project until all authored text is finalized. Text-to-speech voices may be the best solution if scenarios need to be authored in the future and access to voice actors is limited or inconsistent.

ensure that the triggers for different components launched correctly and integrated aesthetic elements like agents smiling when learners answered correctly (see Exhibit 10).

> ***Lesson Learned***
>
> A thorough testing environment can prevent mistakes before the scenario goes live.

Create templates and recycle capabilities: Our authoring system also included template making capabilities to ensure faster scaling in future phases. In the authoring tool, authors can construct item types and define their capabilities and then save these item templates for future use. The scenario templates consist of:

- **Ready-made layouts.** We started by creating templates for the item types known to be on the A+ exam. For us, these included predefined item types such as drop-down selections, check-all-that-apply, drag-and-drop, and multiple choice.
- **Meaningful item grouping.** By grouping items together, the system signals to learners that the items fall under a common theme or should be considered together. Check-all-that-apply questions, for example, can be grouped together, allowing the system to give high-level hints for the group of items, since item-level hints would unintentionally give away correct answers.

Authoring Tool Takeaways

- ✓ Create an authoring tool as soon as your ITS design has stabilized—particularly if you have many scenarios to create or creation will be ongoing as new content arises.
- ✓ Try to systemize how the ITS works so the authoring tool can create new content without much customization.
- ✓ Use the authoring tool as a testing environment. This helps identify problems with the authored content quickly.
- ✓ Incorporate the ability to create templates, especially if there are repeated themes in your content (e.g., limited question types, repeated behaviors, scenarios of a similar nature).

Step 5: Learning and Iterating

An element that is critical to the iterative development of the ITS is feedback from key stakeholders (instructors and learners). For this early stage of development, we opted for a hybrid approach with think-aloud testing and qualitative interviews to gather rich, open-ended information about user behaviors, opinions, and suggested improvements. We also used these sessions to gain additional information about the classroom context, other study materials, and study habits. The results of these interviews can be found in section 3.

Get instructor feedback: Although the ITS is intended for learners, instructors are key to implementation and actual usage—if they do not find the tool valuable, they will not promote it to learners. Therefore, we conducted interviews with most of the IT Support instructors at Per Scholas to understand their opinions and criticisms of the tool. Like with learners, we began by asking Per Scholas instructors to try out the system. We followed this with an interview to understand the barriers they face in teaching, whether this type of ITS would be helpful to them or their learners, and feedback on strengths and weaknesses. We also asked instructors about integrating the ITS into their course operations and what information they would want available to them in a dashboard to help monitor learner usage and progress.

Get learner feedback: Most critically, we interviewed 12 current learners or recent graduates to understand how they used the ITS and obtain their feedback (both positive and negative). We also used this opportunity to learn more about why they enrolled in Per Scholas, their after-course career goals, how they study for their course, and any barriers they experienced in the course. This information helped us to understand more about their goals for Per Scholas (learning valuable career skills vs. passing certification exams) and enables us to better position our supports and identify where we might expand in scale-up phases.

Refine the system: After the interviews, we coded transcripts to create an extensive list of all the feedback we received about how our system should change and tabulate the number of people who gave us this feedback (Appendix C). Then, the University of Memphis sorted the list based on the time it would take to implement these changes, essentially creating a prioritized to-do list. While many items on this list have already been integrated, several will occur in Phase 2, our scale-up phase.

Learning and Iterating Takeaways

- ✓ Identify all the different elements needed to write for each scenario and how they differ from each other.
- ✓ Train authors with illustrative examples and refined templates.
- ✓ Track time spent on authoring for each unit to better estimate how long full production will take and continue to monitor time spent over time as these estimates can change.
- ✓ Be prepared to review and revise frequently! Authoring is an iterative process. Getting content right takes several attempts.

3. Insights on Desirability: Findings From Learner and Instructor Interviews and Per Scholas Managers

To understand the desirability of the ITS prototypes and their fit with end user needs, AIR researchers interviewed Per Scholas instructors and learners using think-aloud and semi-structured protocols. The purpose of these interviews was to answer the following questions:

1. **Who are the learners and what are their motivations?** Here we gained a better understanding of learner experiences, including their motivations to participate in Per Scholas and their goals upon completing their CompTIA A+ certification.
2. **What challenges do learners experience?** Here we sought to understand challenges they have experienced along the way when preparing for the CompTIA A+ exam.
3. **What helps learners succeed?** Here we identified what resources learners perceive as helpful in their studying efforts to ensure the system incorporates elements that are appealing to learners and does not include features learners do not find helpful.
4. **What do learners and instructors think of our ITS prototypes?** Here we received preliminary feedback on the ITS scenarios and interface to discover how learners and instructors perceive the tool and what features we should consider improving.

We conducted these interviews in the winter of 2022–2023. Additional details about interview distribution and our methods can be found in Appendix B.

Who are the learners and what are their motivations?

Interview findings revealed that learners come to Per Scholas from a variety of backgrounds and have unique motivations and goals related to completing their Per Scholas coursework and passing the CompTIA A+ exam. Interviewees shared their stories, describing professional and personal experiences that led them to Per Scholas. The learner profiles in Exhibit 11 share brief but insightful snapshots of these motivations.

Instructors spoke proudly about their learners' accomplishments, many of whom have experienced significant barriers in life. Learners described different lived experiences leading up to joining Per Scholas but often indicated that they shared common goals with their peers when explaining what they wanted to achieve after graduating from the Per Scholas program and receiving the CompTIA A+ certification. They predominantly aspire to enter an industry that can improve financial outcomes for themselves and their families. Learners expressed that they sought to return to a structured education program to help master required skills (e.g., learning the concepts, applying them in labs) and receive support (e.g., instructor and peer guidance, career counseling) to improve readiness for future career moves.

Exhibit 11. Learner Profiles

An educator and digital artist with an interest in web development who needed to find a retraining opportunity in a new industry after experiencing a life-altering medical issue.

A driven night-shift worker experiencing financial hardship who is looking for a big break in an industry that can change his financial and career outlook.

An independent learner who needed a steady program with a road map and progress checkpoints along the way to foster confidence in completing the certification, moving him closer to his goal of acquiring a higher-paying job.

A parent who has worked hard in the food industry all his young adult life and is ready to pursue his dream of entering a field that aligns to his interests and provides greater financial stability.

A jack-of-many-trades who has a vision to bridge their electrician background and IT to pursue a career in creating more equitable housing opportunities.

A career-changer who experienced personal hardships and needed structure and connection to work toward pursuing an industry she believes is the future.

A mature learner who heard about Per Scholas on the radio and felt she had finally discovered a feasible opportunity to pursue her childhood dream of working with computers for a living and becoming self-sufficient at troubleshooting her own computer issues.

A laborer who is taking a pay cut to seek a career that gives his body a much-needed break. He's motivated to rise through the ranks quickly by obtaining additional certifications.

What Challenges Do Learners Experience in Preparing for the Exam?

Our team found it important to understand what challenges learners experience as they study for the exam. This information can help us address these issues in our system to increase the likelihood of learner success.

As previously mentioned, learners come to Per Scholas from different backgrounds and their previous work experience is often not related to IT. Instructors and learners noted that learners' lack of preparation and experience in IT can pose a challenge—specifically, the unfamiliar terminology, acronyms, and technical concepts can be overwhelming. Learners and instructors often noted that the sheer amount of

CHALLENGES IN EXAM PREPARATION

- Lack of preparation and experiences in IT
- Test anxiety
- Issues with self-confidence
- Wavering motivation
- Trouble studying effectively
- Life commitments outside of studying

information covered by the course and the need to memorize large amounts of material can be challenging. Although memorizing is important in preparation for the certification exam, learners also expressed difficulty with connecting the underlying written concepts to real-world situations, such as applying their knowledge appropriately to a technical problem they might encounter in the workplace.

> "And the fact of the matter is, I'm in my living room. So, the real-world application is really existing only in my brain. And I think the obstacle there is that I don't have the logical understanding of what I might experience in a real situation." –*Learner*

A few learners and instructors noted the lack of accessibility considerations in study materials as a challenge. Inaccessible materials and resources prevent some learners from meaningfully engaging in study preparation efforts. Some learners require learning supports such as extended time and auditory features (e.g., text-to-speech). Instructors noted the importance of working closely with learners to understand and address their specific accessibility and learning needs.

Many learners enrolled in Per Scholas are simultaneously employed (32%), sometimes working more than one job, while also navigating other life circumstances such as raising a family, caring for an elderly parent, or coping with an illness. These additional responsibilities often require time management acrobatics to balance studying with other commitments. To alleviate these challenges, any tool developed to serve learners should be time-optimized, accessible, and connected to real-life scenarios.

What Helps Learners Succeed?

We sought to understand the supports learners currently access and find useful so we can continue to build an ITS that is relevant to their learning preferences and addresses unmet needs. Learners have access to a variety of resources to assist them with studying and exam preparation. In our interviews, learners described the resources and sources of information they have access to as well as the extent to which these resources help them learn. They noted that they needed several resources to help them understand the course materials and prepare for the exam. Learners highlighted that connecting with their instructors and peers helps them break down complex concepts or work through specific issues. Although the course textbook is considered comprehensive, learners and instructors mentioned the need for additional information sources (e.g., labs, videos) to bridge written concepts to real-world applications. Several learners and instructors noted the importance of accessibility, such as text-to-speech capabilities, due to different learning preferences and, in some cases, disabilities. Exhibit 12 lists frequently mentioned resources and indicates common themes around why learners found them useful.

Exhibit 12. Frequently Mentioned Resources and Why They Were Useful

Resources	Helpful features					
	# of learners who mentioned resource	Provides visual/ auditory learning	Explains concepts in layman's terms	Aligns with test questions	Has information about practical applications	Provides individual or hands-on help
Videos (e.g., Professor Messer, Mike Meyers)	10	◆	◆	◆		
Instructors	7				◆	◆
Labs	7	◆		◆	◆	◆
Textbooks	5			◆		
Peers	5		◆		◆	◆
PBQs	6			◆		
Online courses (e.g., Udemy)	3		◆	◆		
Guest speakers	1				◆	

Note. PBQs = performance-based questions.

There was variation in learner perceptions of resource utility. While some learners cited the resources in Exhibit 12 as useful, others disagreed. Learners reported that the textbook and Performance Based Questions (PBQs) from the CompTIA website were less useful because they rely on memorization and do not incorporate hands-on learning. Instructors mentioned that resources need to be low cost and ideally free for learners.

What Do Learners and Instructors Think of Our ITS Prototypes?

Overall, learners and instructors shared positive comments about the ITS' value as a study resource.

Learner Feedback

Ten of the twelve learners interviewed said they would use the tool for studying purposes. Learners noted several features of the ITS design that they liked. For example, all interviewees noted that the scenario-based questions contained relevant content that they would expect to

see in their coursework. Several learners noted the helpfulness of the hints and additional explanations provided by the tutor agent. Learners also liked how the items were broken down into specific sections and covered material in isolation. One learner emphasized how the specific feedback limited to one topic would be especially helpful in targeting the parts of the material he struggles with (e.g., subnetting, networking, and ports).

> "I like the concept of it [the ITS] compared to the long list where you have to read a bunch of questions and then answer them. I like the fact that it's specifically categorized for one specific section within the whole lesson plan from start to finish, and then you get to basically practice on it. And it also gives you the feedback in that one particular section." *–Learner*

Most of the learners noted that they liked the interactive format with the tutor agent responding and providing feedback to the learner's responses, which is an aspect of the ITS that is different from the study materials they normally use.

> "I just think that this is a direct improvement over the original base material. It has more features. The audio component directly enables me to memorize something in a different dimension… And I just think that is just more conducive to me learning it." *–Learner*

A few learners reported that the positive affirmations that tutors provide are "encouraging" and it felt "like someone is rooting you on."

The two learners who did not see themselves using the ITS for learning, found it unappealing for different reasons. One learner said he prefers to use more rote study materials such as PBQs that provide a quick summary of what he answered incorrectly. This learner also wanted to speed up the tutor agent when reviewing the answers during the scenarios because he wanted to quickly see the incorrect answers to focus on areas of improvement, rather than proceeding step-by-step though each response. The other learner stated that there was not enough direction on what they were expected to do in the question and that the explanations provided by the tutor agent were difficult to understand (i.e., robotic voices and limited use of layman's terms).

Instructor Feedback

All instructors said that the tool is a helpful study resource for their learners. Similar to learners, instructors liked the feedback provided by the tutor agent and were often surprised by the level of detail in the explanations. They also thought the interactive features were beneficial because the guidance mirrors what they experience in class.

> "So, the computer just verbally explaining things, I feel like it makes it feel very realistic. If I were to explain something to the learners, they are more likely to understand what's going on than them just reading it." –*Instructor*

Instructors noted that the pacing of the scenarios (walking through each item) is appropriate because it forces the learner to slow down and think about what they know and how to apply it. As one instructor put it, "We try to emphasize to learners that it's not just knowing the right answer but explaining why that's the right answer." Instructors also liked that learners were given a second attempt to respond to the items, which encourages learners to think critically and apply their learning.

> "They're [tutor agents] not giving you the answer, they're pointing you toward the answer. And that's what the students truly need. They need to be focused on finding the answer themselves. When you're working a help desk or you're working in a real-world environment, you've got you to rely on first." –*Instructor*

Testing Feedback: Specific Points of Improvement to Consider

Although most learners and all instructors liked the tool, they also shared feedback about improvements the team could consider. Most of the feedback from learners and instructors concerned **stylistic choices** related to the look and feel of the system (e.g., font size, labels, colors). Instructors and learners generally liked the **content** of the tutor's hints, but they were sometimes left wanting more detailed explanations to help them arrive at the correct answer without relying on a process of elimination or being given the answer by the tutor. Learners and instructors also recommended incorporating **an orientation module** to provide system navigation instructions and expectations.

Other points of improvement included **improving accessibility** by integrating text accessibility capabilities (e.g., adding text-to-speech, making the ITS compatible with screen readers, letting the learner control the speed of the tutor agent's speech) and embedding more visualizations. These improvements are critical to ensuring that all learners can meaningfully engage with the tool and access all features.

Our team has begun revised the ITS based on this feedback and will act on the more substantive feedback (e.g., adding more hints to questions) in Phase 2 and Phase 3. Appendix C provides a detailed table of all user feedback and notes when developers plan to address the feedback.

What Do Per Scholas Managers Think About the Usefulness of the ITS Prototype?

AIR and University of Memphis conducted a demonstration with the ITS and shared Phase 1 user testing feedback with Per Scholas managers, during which Per Scholas was able to hear learner and instructor perceptions of the ITS prototype. The prototype was met with enthusiasm and eagerness to continue the work into future phases. Managers appreciated all the feedback and continuous improvement plans based on user testing insights. Managers noted that instructors do not have the capacity to build out the infrastructure for the types of support the ITS offers so it is "amazing" to see a product that will make it easy to create new scenarios within the system. One Per Scholas manager said, "I think it's going to be a game changer!" He explained that the ITS will provide valuable supplemental study material and could help cut down on the number of after-hours questions posed by learners. He also mentioned having wanted to build out a solution like this for over a decade and being excited about seeing that vision realized. Per Scholas managers expressed excitement about building out additional scenarios for the IT Support course and have expressed repeated interest in expanding the scope to use ITS in other courses as well.

4. Lessons Learned, Next Steps, and Conclusions

The work done in Phase 1 demonstrates the feasibility of building an intelligent tutoring system that learners at Per Scholas are interested in using and, for the most part, would find valuable in their studies. During this phase, we learned more about the steps and processes needed to build such a system. Although the key lessons learned can be found in Chapter 2, we distill a few of the most critical lessons here:

- **Assemble a team with complementary talents.** We needed more than engineers to build this system. We were a team of learning scientists, researchers (quantitative and qualitative methodologists, deep content area specialists, and pilot and rapid cycle learning experts), project managers, SMEs, and developers who were in open and frequent communication with each other.
- **Have a clear vision.** Early on, we established the overarching goal of the project—what if an on-demand tutor could walk a learner through a scenario-based question? That question became our North Star, giving us easy answers to some design decisions so we could focus on the tougher problems.
- **Customize content, standardize behaviors.** Every question and scenario in our system is specific to topics learners struggle with. However, to ensure the feasibility and timeliness of the project, we could not let every aspect become customized. We set up clear rules of behavior for the system so our authoring tasks were always clear and the system would behave predictably.
- **Build out tools that will simplify scale-up.** Once we had the barest idea of what these scenario-based questions would look like, the engineering team at University of Memphis created an authoring tool that helped pull the content into a usable program. Although we will need to provide training for Per Scholas staff who want to use the tool, we find it preferable to work in a slightly complex user interface compared with hand coding each scenario.
- **Connect with real users.** As soon as we had a minimum viable version of all three scenarios, we began in-depth interviews with users to inform our next iteration. We took guidance from instructors throughout the design process and found it critical to connect with the intended users as early as we could to understand any potential barriers to use of the tool.

Ending Phase 1 with feedback clarified the next steps of the project. Although we plan to scale the number of scenarios in Phase 2, users and instructors let us know the features needed for the ITS to bring value to most of their learners. Integration into the course materials will also be a key step, finally allowing learners to easily access the ITS within their course learning environment.

In the next phase of our work, we intend to accomplish the following:

- **Create more scenarios.** We will target approximately 12 topics and concepts that learners struggle with, particularly in relation to the existing scenario-based exam items. These are in addition to the three we have developed already. Together, this suite of topics covers key content that instructors believe learners need to master to succeed in their certification exams and in the workplace.
- **Develop an orientation module.** We believe a short introductory module or "guided tour" of the ITS could help orient learners to the tutoring system. In this module, learners will be able to select their conversational agents and assign them roles (student or tutor) to suit their learning preferences. This module can also give learners information on how to leverage all the features and accessibility options.
- **Integrate the scenarios into Canvas and build a dashboard for instructors.** Right now, the system sits outside of the learning management system used by Per Scholas (Canvas), but uptake will depend on the ITS being easy to find and access. Therefore, we intend to integrate the ITS with Canvas and construct a dashboard so instructors and learners can monitor their learning. In interviews with instructors, we learned more about what they would like to know about their learners' interactions with the ITS and have already set up data tracking that can be plugged into the instructor dashboard. Similar information will be displayed to learners as well.
- **Ensure accessibility for all learners.** We will need to ensure that all Per Scholas learners are able to use the ITS if they want. Although much of the ITS is already compatible with accessibility tools like screen readers, we will work to ensure this is true across all question types and will implement new features, such as the ability to adjust speaking speed.
- **Expand the role of the student agent.** Currently, the student agent echoes the learner's mistakes, which may be monotonous for some learners. We will expand the student agent role to include conversations with the tutor about key misconceptions and deep situational reasoning, modeling the process of thinking through questions and the answer choices.

We believe this project could be used as a model for other kinds of training programs or educational contexts, demonstrating how to efficiently and collaboratively build a promising ITS through a strong researcher-practitioner partnership. This project may stir interest in the development of similar systems and even advance learning for ITS use in more traditional education settings. Although the particular system being built in this partnership will likely only apply to others interested in IT or this specific certification test, the structures being implemented for the first time on this project have tremendous potential to improve the speed of building other ITS and improving learning in diverse sectors.

References

Baker, R.S.J.d., Corbett, A.T., Koedinger, K.R., Evenson, S.E., Roll, I., Wagner, A.Z., Naim, M., Raspat, J., Baker, D.J., & Beck, J. (2006). Adapting to when students game an intelligent tutoring system. In M. Ikeda, K. D. Ashley, & T-W. Chan (Eds.), *Proceedings of the 8th International Conference on Intelligent Tutoring Systems* (pp. 392–401). Springer.

Biswas, G., Jeong, H., Kinnebrew, J. S., Sulcer, B., & Roscoe, R. O. D. (2010). Measuring self-regulated learning skills through social interactions in a teachable agent environment. *Research and Practice in Technology Enhanced Learning*, *5*(2), 123–152.

Coursera. (2022). *What is the CompTIA A+ certification? A certification to start your IT career*. https://www.coursera.org/articles/what-is-the-comptia-a-certification-what-to-know

Duran, D. (2017). Learning-by-teaching. Evidence and implications as a pedagogical mechanism. *Innovations in Education and Teaching International, 54*(5), 476–484.

El Saadawi, G. M., Azevedo, R., Castine, M., Payne, V., Medvedeva, O., Tseytlin, E., Legowski, E., Jukic, D. & Crowley, R. S. (2010). Factors affecting feeling-of-knowing in a medical intelligent tutoring system – the role of immediate feedback as a metacognitive scaffold. *Advances in Health Sciences Education, 15*(1), 9-30.

Epstein, M., Lazarus, A. D., Calvano, T. B., Matthews, K. A., Hendel, R. A., Epstein, B. B., & Brosvic, G. (2002). Immediate feedback assessment technique promotes learning and corrects inaccurate first responses. *The Psychological Record, 52*, 187-201.

Ferguson, S. (2023, May 2). *Understanding America's labor shortage*. U.S. Chamber of Commerce. https://www.uschamber.com/workforce/understanding-americas-labor-shortage

Ghayad, R. (2023). *Why skills-first hiring is the solution to the global talent shortage.* World Economic Forum. https://www.weforum.org/agenda/2023/04/growth-summit-2023-why-skills-first-hiring-is-the-solution-to-the-global-talent-shortage/

Groshen, E. L. & Holzer, H. (2021). Labor market trends and outcomes: What has changed since the Great Recession? *The ANNALS of the American Academy of Political and Social Science, 695*(1), 49-69.

Hendra, R., Greenberg, D. H., Hamilton, G., Oppenheim, A., Pennington, A., Schaberg, K., & Tessler, B. L. (2016). *Encouraging evidence on a sector-focused advancement strategy.* https://www.mdrc.org/sites/default/files/2016_Workadvance_Final_Web.pdf

Kanengiser, H. & Schaberg, K. (2022). Employment and earnings effects of the WorkAdvance demonstration after seven years. https://www.mdrc.org/sites/default/files/WorkAdvance_7-Year_Report.pdf

Katz, L. F., Roth, J., Hendra, R., & Schaberg, K. (2022). Why do sectoral employment programs work? Lessons from WorkAdvance. *Journal of Labor Economics, 40*(S1) S249–S291.

Kehrer, P., Kelly, K., & Heffernan, N. (2013). Does immediate feedback while doing homework improve learning? In C. Boonthum-Denecke & G. M. Youngblood (Eds.), Proceedings of the Twenty-Sixth International Florida Artificial Intelligence Research Society Conference (pp. 542-545). AAAI Press.

Kulik, J. A. & Fletcher, J. D. (2016). Effectiveness of intelligent tutoring systems: A meta-analysis review. *Review of Educational Research, 86*(1), 42-78.

Ma, W., Adesope, O. O., Nesbit, J. C., & Liu, Qing. (2014). Intelligent tutoring systems and learning outcomes: A meta-analysis. *Journal of Educational Psychology, 106*(4), 901-918.

Razzaq, L. & Heffernan, N. T. (2006). Scaffolding vs. hints in the ASSISTment system. In M. Ikeda, K. D. Ashley, & T-W. Chan (Eds.), *Proceedings of the 8th International Conference on Intelligent Tutoring Systems* (pp. 635-644). Springer.

Schaffhauser, D. (2020). Report: Top 4 barriers to college completion. Campus Technology. https://campustechnology.com/articles/2020/11/20/report-top-4-barriers-to-college-completion.aspx

Steenbergen-Hu, S., & Cooper, H. (2013). A meta-analysis of the effectiveness of intelligent tutoring systems on K–12 students' mathematical learning. *Journal of Educational Psychology, 105*(4), 970–987.

Steenbergen-Hu, S., & Cooper, H. (2014). A meta-analysis of the effectiveness of intelligent tutoring systems on college students' academic learning. *Journal of Educational Psychology, 106*(2), 331–347.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist, 46*(4), 197–221.

Williams, B., Bitar, J., Polk, P., Nguyen, A., Montague, G., Gillispie, C, Waller, A., Tadesse, A., & Elliott, K. C. (2022). *For student parents, the biggest hurdles to a higher education are costs and finding child care*. The Education Trust. https://edtrust.org/resource/for-student-parents-the-biggest-hurdles-to-a-higher-education-are-costs-and-finding-child-care/

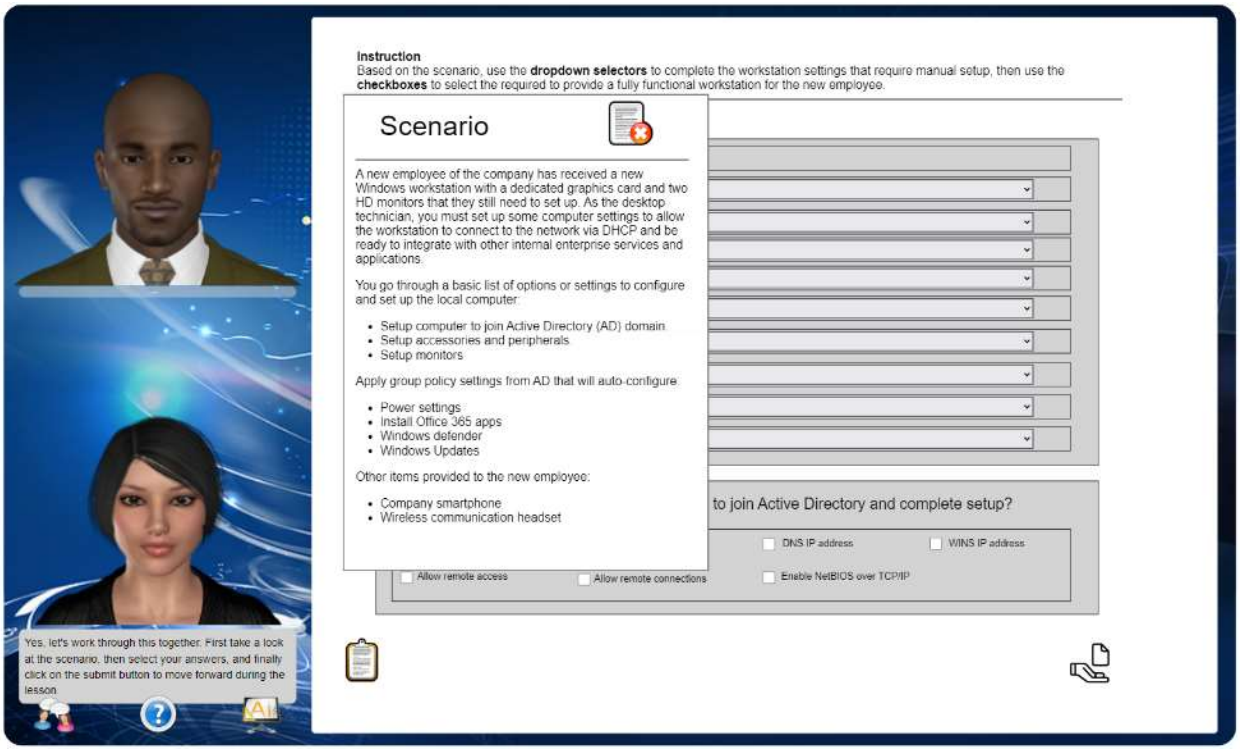
Xu, Z., Wijekumar, K. (K.), Ramirez, G., Hu, X., & Irey, R. (2019). The effectiveness of intelligent tutoring systems on K-12 students' reading comprehension: A meta-analysis. *British Journal of Educational Technology, 50*(6), 3119–3137.

Appendix A. ITS Walk-Through

To begin developing the prototype, we chose three scenario-based questions that focus on existing concepts that appear on the certification exams: troubleshooting display and startup issues (3.1), preparing a workstation for a new employee (1.3), and understanding the qualities of various authentication systems (2.5). Although each of the three scenarios differ from each other in format and content, the interaction patterns remain the same across questions.

To begin the scenario-based lesson, the learner is first introduced to the tutor and student agents onscreen. The tutor agent leads the session, evaluating the correctness of the responses, delivering hints, and giving explanations. The student agent's current role is to agree with the learner when they give a wrong answer, allowing the tutor agent to correct the student agent rather than the learner. This serves to soften negative feedback and encourage the learner to try again. In Phase 1, the tutor and student agents are pre-selected (see Exhibit A1), but in future phases, we plan to have an introductory module that allows learners to customize their agents.

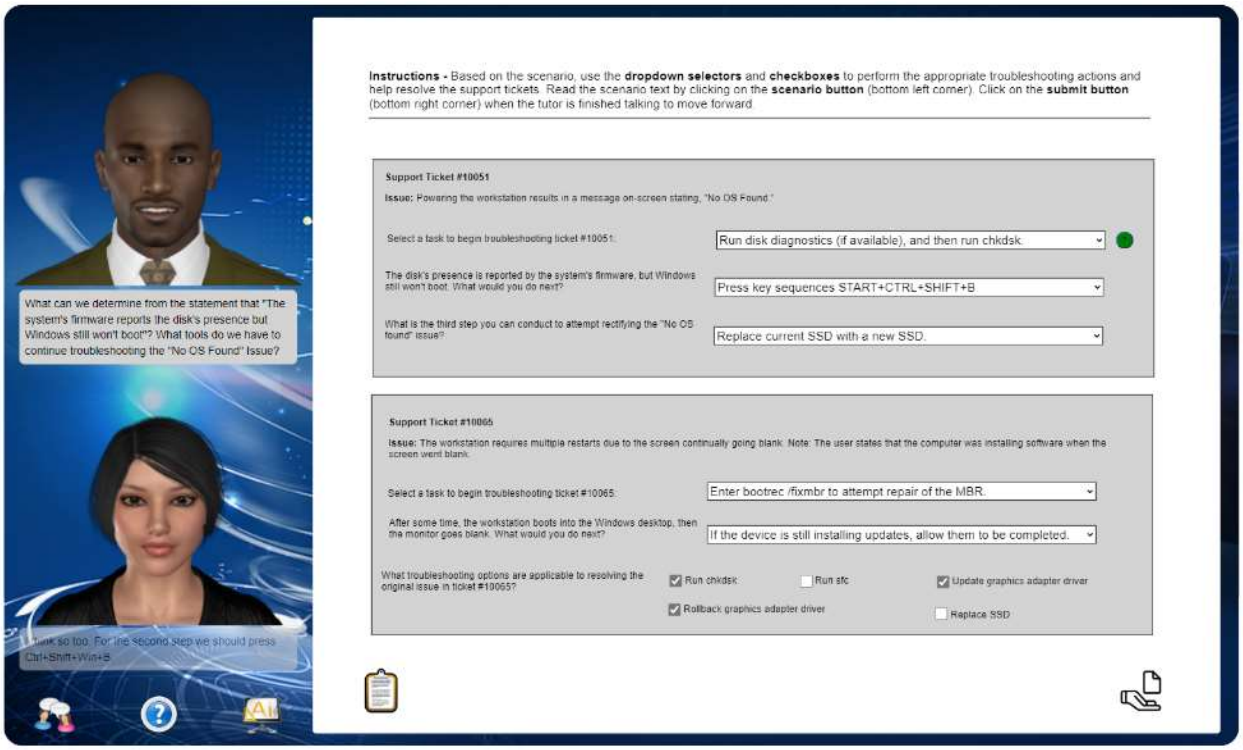
Exhibit A1. Scenario 1.3 With Scenario Text



To begin the tutoring, learners are prompted to read the scenario and then answer all questions onscreen. The scenario is closed with the red X document icon and may be reopened

with the clipboard icon. Once answers have been selected, the tutor agent begins to step through the items with the learner. Each item is evaluated in turn (with one exception, discussed below). First, the tutor will evaluate the answer the learner has selected. If the answer selected is correct, the tutor agent will say so explicitly and explain why it is correct in case the learner was guessing or uncertain. If the answer is incorrect, the student agent will agree with the learner and the tutor agent will deliver direct, negative feedback, followed by a hint. The hint typically suggests the learner think more deeply about a certain aspect of the scenario or question, or to recall concepts they learned in class ("remember the three A's"). The learner is given an opportunity to amend their answer, after which point, the tutor agent will either give positive or negative feedback and an explanation of the correct answer. For check-all-that-apply questions, hints are delivered more broadly for the entire group of items, because direct hints would give away the answer. Once the hints are delivered for this section, the tutor agent then steps through each of the items, evaluating each one as either correct or incorrect with further explanations.

Exhibit A2. Scenario 3.1 With the Tutor Delivering a Hint After an Incorrect Selection



When the tutor agent moves on to the next item, a green or yellow question mark button is left behind for learners to click (see Exhibit A2). Green indicates that it is an item the learner answered correctly on either their first or second attempt, and yellow indicates that the learner ultimately did not answer the item correctly. This provides visual feedback at the end of the

scenario as to the learner's performance. When clicked, the question marks, or summaries, provide a recap of the correct answer and, if answered incorrectly, an explanation of why the wrong answer was incorrect These often give more detailed explanations that would be tedious for the agent to say aloud.

The system currently contains many features to assist with accessibility, and other features will provide a richer experience once embedded into the course. Learners work through the scenario at their own pace by repeatedly pressing the submit button, allowing them to pause, think, take notes, refer to their other course materials, or take a break as needed and not miss any of the tutoring. Learners may also review their interactions with the tutor and student agents at any point in the scenario by clicking on the far-left button under the student agent to see a transcript of the session to that point. The button to its left will be a "help" icon (to be fully implemented in Phase 2), and the next button over will, once integrated into Canvas, link the learner to a helpful video, lab, textbook excerpt, or any other piece of multimedia that the learner can use to gain additional information about the topic.

Appendix B. User Think-Aloud and Interview Recruitment and Methods

Recruitment. The team recruited participants through word-of-mouth, emails from instructors to their learners, and Canvas announcements posted by Per Scholas staff to learners enrolled in the IT Support course. Interviews were voluntary. We offered participants a $30 gift card as compensation for their time. The interviewee sample included instructors and learners in courses of various formats, including online, in-person, and blended courses. The team distributed testing with learners and instructors across the three scenarios (see Exhibit B1 below).

Exhibit B1. Interviewee Mode of Instruction and Scenarios Tested

Interviewee type	Online	In person	Blended	Scenario 1.3	Scenario 3.1	Scenario 2.5
Learners (12)	7	2	3	4	4	4
Instructors (7)	3	2	2	5	2	0[2]

Interview format. We followed a think-aloud interview protocol where interviewees navigated through one of three scenario-based questions in an ITS environment while voicing their impressions of the content and interface in real time.[3] Following the think-aloud interview, interviewers asked a series of questions to better understand the interviewee's overall experience with the system (e.g., likable features, challenges experienced completing the scenario, and considerations for ITS builders). The team also gathered information about the learners' motivations to participate in Per Scholas, the study materials that learners access and find useful, and what challenges learners experience when preparing for the CompTIA A+ exam.

[2] No instructors tested 2.5, because instructors did not have availability to participate in an interview after 2.5 was completed.
[3] We developed protocol questions for each portion of the interview and received approval from AIR's internal Institutional Review Board (IRB) and Data Governance Board.

Appendix C. Specific User Feedback Table

Scenario #	Specific user feedback	# of interviewees and type (learner, instructor, both)	Address now	Address in Phase 2	Address across phases (Phase 2–4)	Do not plan to address
All	Increase font size overall	17 (Both)	◆			
All	Place label on scenario and submit icons	13 (Both)	◆			
All	Provide an orientation to the module, including how to navigate, direction on what they should expect and do	4 (learner) 4 (instructor)	◆			
All	Would like additional explanations and hints from tutors (e.g., help them arrive at the correct answer by providing additional resources to reference, provide more information about why their answer was incorrect)	9 (learner) 2 (instructor)			◆	
All	Would prefer to be able to move the scenario around the screen instead of having to click in and out of it when they need to refer back to it	5 (instructor) 3 (learner)	◆			
All	Text-to-speech voices, especially the student agent's voice, sound robotic	4 (learner) 2 (instructor)	◆			
All	Spell out acronyms	4 (learner) 1 (instructor)	◆			
All	Prefers the system not go over every answer one by one after submitting. Prefers summary and target incorrect answers	1 (instructor) 6 (learner)				◆

Scenario #	Specific user feedback	# of interviewees and type (learner, instructor, both)	Address now	Address in Phase 2	Address across phases (Phase 2–4)	Do not plan to address
All	Would prefer colors of incorrect answers be red	2 (learner) 2 (instructor)	◆			
All	Text accessibility options (e.g., text-to-speech, compatible with screen readers, let reader control the speed of tutor speech, tutor text disappears too quickly)	1 (learner) 3 (instructor)		◆		
All	Make the additional hint circles more obvious and clickable instead of hovering (e.g., lead the user to use them). Several testers did not realize the circles provided additional information	4 (learner) 2 (instructor)	◆			
All	Confusion regarding student agent's role	4 (learner) 3 (instructor)	◆	◆		
All	Make compatible with additional devices (e.g., mobile)	2 (instructor)				
1.3	Would prefer to have additional opportunity/attempts to answer questions correctly	2 (learner) 1 (instructor)		◆		
1.3 and 2.5	Would prefer hints to include more layman's terms	3 (learner)		◆		
2.5	Would prefer the tutor not try to say their name	1 (learner)		◆		
1.3	Include gamification elements	1 (learner)				◆
3.1	Add "select all that apply" to last question	1 (learner)				◆

About the Team

AIR Team

Dr. Whitney Cade, senior researcher, is the principal investigator for this project. She has expertise in experimental evaluation methods, investigating the impacts and implementation of educational technologies and project leadership. Her research interests include STEM learning, applying ITS to novel contexts, and understanding learner engagement during technology use.

Samia Amin, managing director, is the project director for this project. She is passionate about accelerating evidence-driven innovation in workforce programs. She brings strong expertise in designing and executing complex pilot programs; combining behavioral insights, human-centered design and rapid-cycle learning; and building practitioner capacity for applying evidence to action.

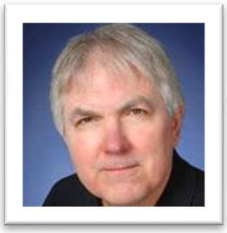
Alex Bishop, researcher at AIR, is the qualitative task lead for this project. She has expertise in qualitative research and methods, formative evaluation, and project management. Her interests include learning about unique user contexts and experiences to inform product or intervention design and implementation.

Cecilia Xuning Zhang, researcher, is the project manager for this project. She is a certified Project Management Professional with three years of experience managing diverse clients, contracts, and teams. She also has technical expertise in leading user experience research and managing data collection for large-scale impact studies focusing on learning technologies.

University of Memphis Team

Dr. Xiangen Hu, professor of Psychology and dean at Central China Normal University, is the lead engineer for this project. His research focuses on categorical data analysis, knowledge representations, computerized tutoring, advanced distributed learning, and natural language processing.

Dr. Keith Shubeck, post-doctoral student, is the project director for the Memphis team. He has more than a decade of experience working with intelligent tutoring systems. His research focuses on vicarious learning in educational technology and the development, assessment, and implementation of ITS.



Dr. Art Graesser, professor emeritus, is the senior advisor for this project. He is a recognized expert in the fields of cognitive science, discourse processing, and the learning sciences, with more specific interests that include question asking and answering, tutoring, reading, text comprehension, artificial intelligence, and human-computer interaction.

Dr. Brent Morgan, research scientist, served as an advisor for this project. His experience lies in the construction and understanding of intelligent tutoring systems. His research focuses on ITS and bidirectional adaptability in human-computer interaction.

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