ONR STEM Grand Challenge

Extensible Adaptive System for STEM Learning

Contract # N00014-12-C-0535

Raytheon BBN Technologies Corp. (BBN) Reference # 14217

In fulfillment of contract deliverable items # A003

System Requirements / Concept Report

Revised on March 26, 2013

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Report Documentation Page

1. REPORT DATE **MAR 2013**	2. REPORT TYPE	3. DATES COVERED **00-00-2013 to 00-00-2013**
4. TITLE AND SUBTITLE **ONR STEM Grand Challenge**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Raytheon BBN Technologies Corp,10 Moulton St.,Cambridge,MA,02138**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

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1   Introduction

This is the System Requirements / Concept Report (CDRL Data Item #A003) for EAITS, an extensible and adaptive STEM Learning System that BBN is developing under the ONR STEM Grand Challenge (GC) Program, Contract # N00014-12-C-0535. EAITS will embody algorithmic research and system development for high-school and college level advanced learning systems. These learning systems will employ state-of-the-art pedagogical and computation techniques to improve student proficiency in targeted subject areas.

For the ONR STEM GC Program, BBN will develop a prototype version of EAITS and demonstrate its customization to the SAT Physics curriculum. In this document, we first will present a conceptual overview describing the principles and plans for EAITS development and evaluation. The second part of this document specifies the software requirements that will be met by the SAT Physics version of EAITS.

2   Conceptual Overview

The EAITS will advance the state-of-the-art in learning technologies through the fusion of multiple forms of adaptive support with highly effective learning activities. Each of these forms of support and activities have been individually shown to be effectively in terms of improving learning outcomes in prior work. Through meticulous software integration and careful coordination achieved by statistical models, we can close the gap between the efficacy of automated learning systems that are scalable for mass use and the 2σ efficacy of scarcely available human tutors.

The SAT Physics version of EAITS will be an advanced learning system that allows high-school students to improve their proficiency at solving SAT-style Physics problems. The system achieves this through a two learning activities. First, EAITS will allow students to engage in learning through problem solving. Second, students can explore multimedia instructional content such as videos about Physics concepts. The student can also participate in both of these learning activities in a self-paced, anytime, anywhere manner using a variety of devices and platforms that have a standards compatible web-browser.

The learning efficacy of this system will be amplified through the use of personalized adaptive tutoring that in integrated in both the learning activities described above. The tutor will use comprehensive student modeling in combination with a domain model and rigorous analysis of the student's actions in the learning environment to constantly update and adapt its beliefs about proficiencies and preferences of the student. For example, if a student demonstrates the inability to solve a problem involving the concept of *resistivity*, the tutor updates it belief about the student's proficiency in this concept and may decide to initiate interventions that will lead to the improvement in this the student's knowledge. The EAITS tutor will be capable of using multiple forms of support to tailor the interventions delivered to the student including the use of corrective, reflective, and engagement support. Furthermore, the intervention presented to the student will be informed by prior observations (captured in the student model) such as the belief that a natural language dialog may be more effective for certain learners than the use of instructional videos.

The tutor will also use data-driven assessment model to estimate and predict the expected performance of a student on standardized tests within the topics covered by the system. This assessment capability will serve as a feedback mechanism that regulates the balance between tutor and student initiative during learning activities.

In addition to the SAT Physics version of the EAITS, the underlying platform will provide authoring tools that support development and maintenance of high-quality learning content that can be used within the EAITS. These tools can be used by domain experts and system administrators to add and modify knowledge sources used by SAT Physics EAITS in an ongoing manner without the need to modify the underlying software platform.

3   Requirements

This report is a living document that captures on-going requirements discussions between ONR and BBN. Early versions will focus on broad requirements such as generic system functionality. Later versions will refine the requirements to include specific operating characteristics such as deployment specifications.

The following sections are organized by requirement categories. Sections itemize specific requirements, each of which have a unique identifier in support of traceability for design, testing, and validation plans.

3.1   Capability Requirements

Req. 1.   EAITS shall allow students to learn about SAT-level Physics for the following topics:

    Req. 1.a   Electromagnetism

Req. 2.   Learning in EAITS shall be enabled through multiple learning activities including

    Req. 2.a   Structured exploration of rich instructional content integrated within the learning environment including

        Req. 2.a(i)   Text

        Req. 2.a(ii)   Videos

        Req. 2.a(iii)   Natural Language Dialogs

    Req. 2.b   Interactive problem solving covering the complete range of SAT Physics problem types including

        Req. 2.b(i)   Verbal

        Req. 2.b(ii)   Pictorial/Spatial

        Req. 2.b(iii)   Graphical

        Req. 2.b(iv)   Symbolic

        Req. 2.b(v)   Numerical

        Req. 2.b(vi)   Recall

        Req. 2.b(vii)   Single-Concept Problem

        Req. 2.b(viii)   Multiple-Concept-Problem

Req. 3.   EAITS shall provide multiple forms of automated, personalized support to the learning activities listed in Req 2.b including

    Req. 3.a   Corrective support through use of problem-specific tutor models

Req. 3.b   Reflective support through integration of tutorial dialog with problems

Req. 3.c   Engagement support through the use of timely social interaction strategies

Req. 4.   EAITS shall provide reporting about the learners that includes

Req. 4.a   Quantitative proficiency assessment through the use of automatic assessment algorithms built on student modeling and machine learning algorithms

Req. 4.b   An student profile that visually summarizes the learning trajectories, skills, and achievements of each student

Req. 5.   EAITS shall provide an authoring suite that can be used by content developers (such as educators and domain experts) to maintain and extend the delivered EAITS. These authoring tools will include the following integrated tools

Req. 5.a   Domain/curriculum authoring tool

Req. 5.b   Problem and tutoring support authoring tool

Req. 5.c   Tutorial dialog authoring tool

Req. 6.   EAITS shall incorporate a data repository that captures and stores time-stamped events logs generated through the use of the EAITS

3.2   Design Requirements

Req. 7.   EAITS separate content and code to allow extension of the system in terms of

Req. 7.a   Inclusion of additional topics in the SAT Physics curriculum

Req. 7.b   System tailoring to support other STEM learning domains

Req. 8.   EAITS shall be modular and flexible to allow integration of new algorithms and models, specifically for

Req. 8.a   Tutor/support modeling

Req. 8.b   Student modeling

Req. 8.c   Automated assessment

Req. 9.   The EAITS environment used by students to access the learning activities shall be cross-platform compatible through the use of standardized web technologies

Req. 10.   The EAITS database and web server integrations shall be scalable to allow the use of existing technologies (such as distributed servers and cloud computing) for deployment of the system to large number of users

3.3   Compute Resource Requirements

Req. 11.   EAITS shall run on commodity hardware

Req. 12.   EAITS shall operate on both the Linux or Windows operating system

Req. 13.   EAITS shall operate in a standard TCP/IP network environment including deployment on Internet accessible webservers

3.4   Documentation Requirements

Req. 14.   EAITS shall include installation and maintenance documentation

Req. 14.a   Installation and maintenance documentation shall be written to enable computer professionals to receive a delivery of EAITS (e.g., on a CD-ROM), and

set up the demonstration system on appropriate hardware and software environment.

Req. 15. EAITS shall include tutorials for

Req. 15.a Students on the use of the EAITS learning environment

Req. 15.b Content developers on the use of authoring tools

Req. 16. EAITS shall include web service documentation that can be used by computer professionals to modify the integration between the EAITS learning environment and corresponding web services

3.5 Interface Requirements

Req. 17. The EAITS shall have a class design (included in Req. 14) that provides abstractions for extension of components (listed in Req. 8) with new algorithms

Req. 18. EAITS web services shall be well-defined and unambiguous

Req. 19. EAITS web services shall be defined in the EAITS web service documentation

Req. 20. EAITS shall be configurable to turn off specific capabilities which can be used to perform ablation assessments and analyses of the system learning outcomes

3.6 Security Requirements

Req. 21. EAITS shall apply best-practices for authenticated access to the learning environment and authoring tools

Req. 22. EAITS authoring tools shall use an automatic source control and configuration management system

Req. 23. The EAITS database shall separate personally identifiable information (PII) from event logs to facilitate anonymized analysis of pedagogical data

3.7 User Requirements

Req. 24. EAITS shall allow participation in learning activities (listed in Req. 2) by

Req. 24.a Students for pedagogical purposes

Req. 24.b System developers for demonstration purposes

Req. 25. EAITS shall allow development of knowledge sources/content by subject matter experts such as educators and content developers

3.8 Performance Requirements

Req. 26. EAITS performance requirements are to be determined in the context of deployment scenarios and in conjunction with representatives from the Government bodies interested in transition the system to real users within their organizations.