Special Notice 11-SN-0019

Special Program Announcement for 2011 Office of Naval Research

"OFFICE OF NAVAL RESEARCH STEM GRAND CHALLENGE – ADAPTIVE, GENERALIZABLE INTELLIGENT TUTORS FOR STEM AND NAVAL TRAINING AND EDUCATION"

I. INTRODUCTION:

This announcement describes a *revolutionary* research program, STEM GRAND CHALLENGE – ADAPTIVE, GENERALIZABLE INTELLIGENT TUTORS FOR STEM AND NAVAL TRAINING AND EDUCATION to be launched under the ONR BAA 11-001, Long Range Broad Agency Announcement for Navy and Marine Corps Science and Technology which can be found at http://www.onr.navy.mil/Contracts-Grants/Funding-Opportunities/Broad-Agency-Announcements.aspx. The research opportunity described in this announcement specifically falls under numbered paragraph 1 of the Warfighter Performance Human and Bioengineered Systems (Code 341) sub-section. The submission of proposals, their evaluation and the placement of applied research contracts and grants will be carried out as described in that Broad Agency Announcement.

The purpose of this announcement is to focus attention of the scientific community on (1) the area to be studied, and (2) the planned timetable for the submission of white papers and proposals.

II. TOPIC DESCRIPTION:

The proposed topic will lead to new approaches for building adaptive and individualized intelligent tutors for STEM training and education that are able to:

- Increase comprehension of instructional content over a fixed teaching duration and curriculum
- Train to higher standards of competence (e.g., expertise), not simply enabling better recall
- Accelerate the development of problem solving, reasoning, and decision-making skills

The program will pursue a wide variety of approaches that address ***six i***ssues that are key to developing the next generation of intelligent tutoring systems for STEM applications: 1) Designing computational cognitive models of student performance; 2) Enabling realistic and effective student – intelligent tutor interactions; 3) Creating individually-tailored instructional strategies for delivering a large corpus of course material; 4) Generalizing the underlying technologies to multiple educational domains and populations; 5) Using the most current empirical research on the science of learning pedagogical approaches (e.g., self-explanation); and 6) Designing tools for reducing the time and expertise needed to build these tutors.

Background:

Today's approaches to training and education must change if our Nation is to retain preeminence in the dynamic global workforce. The 2011 Chief of Naval Operations' Guidance (CNOG 2011) specifically calls for focused efforts to advance STEM education and grow the top technical talent required to lead tomorrow's Navy and Marine Corps. President Obama has also provided a short list of STEM priorities

that includes expanding STEM education and career opportunities. Our Nation requires citizens who have basic math and engineering knowledge, technical acumen, and the ability to reason and make informed decisions using scientific knowledge, methods and principles.

Traditional teaching methods rely on the schoolhouse approach, with one instructor teaching many students. This approach typically targets the "average" student, leaving above-average students bored and below-average students disengaged. Numerous studies have shown that the ideal way to teach is through one-to-one interactions between teachers and students, leading to performance improvements of up to two standard deviations – roughly two-letter grade improvements compared to the traditional classroom approach. Nevertheless, it is often difficult and costly to provide this level of individualized interaction to students, especially to those students in underserved areas.

At the same time, there is increasing use of educational technologies to augment classroom instruction throughout the United States. These technologies include intelligent tutors, video games, simulations, computer-based testing, online education, and immersive learning environments. Technology-based learning tools allow students the flexibility and convenience of education and training with pace, content, and sequencing appropriate for them as individuals. Moreover, numerous studies document that online or mobile computer-based, simulation-based, game-based, and intelligent tutoring technologies all positively impact student learning effectiveness.

One of the most stable findings in comparisons of technology-based instruction with conventional instruction is that technology-based instruction can reduce time to learn. Orlansky and String (1977) found that reductions in time to reach instructional objectives averaged about 54 percent in their review of 13 technology-based military training programs. Fletcher (2001) reported an average time reduction of 31 percent in 6 assessments of interactive multimedia instruction applied in higher education. Kulik (1994) reported time reductions of 34 percent in 17 assessments of technology used in higher education and 24 percent in 15 assessments of adult education. Overall, it seems reasonable to expect technology-based instruction to reduce the time it takes students to reach a variety of objectives by about 30 percent. Most importantly, these time-savings are coincident with significant improvements in learning. In a review of findings from 233 studies, Fletcher (2001) found an overall effect size of 0.39 standard deviations for technology-based instruction, and an effect size of 0.84 from 47 studies of interactive multimedia instruction, suggesting overall improvements from 50th percentile to 65th and 80th percentile performance respectively.

Despite these promising results, current technical capabilities fall well short of replicating the two standard deviation performance improvements of one-to-one live instruction. Moreover, current approaches to intelligent tutor design do not support design, reuse and scalability of these technologies to multiple domains and multiple student populations. Consequently, developing effective intelligent tutors is often prohibitively costly.

Objectives:

The objective of the Office of Naval Research's STEM Grand Challenge Special Notice is to develop cost-effective, generalizable instructional tutors for STEM training and education that can raise a student's

performance by at least two standard deviations. Achieving this objective requires a concerted, multi-disciplinary effort to place science-based instructional technologies into the hands of students across the socio-economic spectrum and may encompass a broad range of capabilities including desktop, mobile, and gaming platforms. The STEM Grand Challenge will provide the right blend of incentive, risk and benefit to revolutionize the state of the art in intelligent tutors. Successful proposals will focus on developing innovative, scalable, and affordable technologies that blend the best pedagogical approaches with cost-effective design solutions that enable broad dissemination of these technologies to a wide range of students.

Performers, selected on the basis of white paper/proposal evaluations, will compete in developing STEM-based intelligent tutors that produce educational performance improvements of up to two standard deviations in a middle to high school setting, and that generalize to a Naval student audience, with similar results. While each performer will need to include training effectiveness evaluations in its efforts, overall performance results will be evaluated by an independent third party. The intelligent tutor should focus on curriculum content from one or more STEM domains and/or core capabilities that facilitate STEM education, such as reading comprehension. The tutor should be tailored to one or more grade levels in the middle school to high school continuum (Grades 7-12). Curriculum-blending solutions are encouraged (e.g., reading comprehension for mathematics word problems; reading comprehension skills for scientific and technical documents), as are classroom-to-Navy focused solutions (e.g., physics or math in the classroom leading to principles of electrical engineering in the Navy schoolhouse). Careful attention should be applied in selecting the domain and grade levels, in order to ensure that the tutor and tutoring approach will successfully address both classroom and Navy training needs and audiences. Solutions may be based on laptop or handheld computers or combinations thereof, must address the challenges indicated in the topic description section, and must satisfy the research area requirements listed below.

Research Areas:

Specific technology challenges to be addressed by this Grand Challenge include: 1) Dynamic, flexible, low cost, and OPEN Architecture networks that fully support the current and anticipated suite of training technologies; 2) Software technologies and capabilities that mirror the interactions between world class teachers and individual students to provide a one-on-one tutorial experience; 3) Automated knowledge elicitation and knowledge engineering efforts necessary for developing instructional content; 4) Science-based understanding of how students in different age groups learn; 5) Authoring techniques that allow both students and local educators to produce and/or edit effective educational materials; 6) Instructional techniques and methods that are the most effective and appropriate for achieving specific instructional objectives; 7) Emerging technologies, such as machine learning and natural language processing as well as theories of learning, like meta-cognition , cognitive load theory, self-explanation, game-based training and rehearsal-through-testing.

The Grand Challenge will proceed as a three-year, two-phase effort with up to four teams selected for Phase 1 and up to two teams selected for Phase 2:

- Phase 1 (Two Years): Develop an intelligent tutor technology for a STEM curriculum for one or more grade levels in the middle school to high school continuum, based on the criteria outlined in this section. The team(s) most closely demonstrating *two* standard deviation improvements in knowledge retention, reasoning and decision-making skills, and problem solving, with associated cost effectiveness assessments based on return on investment and total ownership cost models, will be invited to submit proposals for Phase 2 funding.

- Phase 2 (One Year): Adapt the Phase 1 tutoring capability to a Department of the Navy-specific training populations and learning effectiveness criteria. The winning team or teams will be the ones to demonstrate a tutor that most cost effectively produces *two* standard deviation improvements in knowledge retention, reasoning skills & problem solving, using similar assessment approaches to those in Phase 1.

III. WHITE PAPER SUBMISSION

White papers should not exceed 4 single-sided pages, exclusive of cover page and resumé of principal investigator, and should be in 12-point Times New Roman font with margins not less than one inch. The cover page should be labeled "White Paper for STEM GRAND CHALLENGE – ADAPTIVE, GENERLIZABLE INTELLIGENT TUTORS FOR STEM AND NAVAL TRAINING AND EDUCATION" and include the following information: title of the proposed effort, technical point of contact, telephone number, fax numbers, and e-mail address. The 4-page body of the white paper should include the following information: (1) Principal Investigator; (2) Relevance of the proposed effort to the research areas described in Section II; (3) Technical objective of the proposed effort; (4) Technical approach that will be pursued to meet the objective; (5) A summary of recent relevant technical breakthroughs; and (6) A funding plan showing requested funding per fiscal year. A resumé of the Principal Investigator, not to exceed 1 page, should also be included after the 4-page body of the white paper.

White papers are required for all offerors seeking funding. Each white paper will be evaluated by the Government to determine whether the technology advancement proposed appears to be of particular value to the Department of the Navy. Only the authors of white papers that appear to be of particular value to the Department of the Navy will be invited to submit full proposals. Initial Government evaluations and feedback will be issued via e-mail notification from the Technical Points of Contact.

Detailed Full Proposals (Technical and Cost volumes) will be subsequently encouraged from those offerors whose proposed technologies have been identified through the above referenced e-mail as being of "particular value" to the Government. However, any such encouragement does not assure a subsequent award. Full Proposals may not be submitted by offerors whose white papers were not identified as being of particular value to the Navy.

For white papers that propose efforts that are considered of particular value to the Navy but either exceed available budgets or contain certain tasks or applications that are not desired by the Navy, ONR may suggest a full proposal with reduced effort to fit within expected available budgets or an effort that refocuses the tasks or application of the technology to maximize the benefit to the Navy.

White papers should be submitted electronically to the program technical points of contact, LCDR Joseph Cohn and Dr. Ray Perez. Their e-mail addresses appear at the end of this Special Notice. These white papers shall be in Microsoft Word or Adobe PDF format.

To ensure full, timely consideration for funding, white papers should be submitted no later than 01 August 2011. White papers received after that date will be considered as time and availability of funding permit.

The planned date for completing the review of white papers is 31 August 2011.

IV. FULL PROPOSAL SUBMISSION AND AWARD INFORMATION

Full proposals (including one technical volume and one cost volume) should be submitted under ONR BAA11-001 by 30 September 2011. Full Proposals received after that date will be considered as time and availability of funding permit.

ONR anticipates that both grants and contracts will be issued for this effort. Proposals for contracts should be submitted in accordance with the instructions at Section IV, Application and Submission Information, item 2.b., Full Proposals of ONR BAA 11-001. Full proposals for grants should be submitted in accordance with the instructions at Section IV., Application and Submission Information, item 5., Submission of Grant Proposals through Grants.gov, of ONR BAA 11-001. All full proposals for grants must be submitted through www.grants.gov. All attachments to the application should also include this information to ensure the proposal and its attachments are received by the appropriate Program Office. The following information must be completed as follows in the SF-424 to ensure that the grant application is directed to the correct individual for review: Block 4a, Federal Identifier: enter N00014; Block 4b, Agency Routing Number: Enter the Program Office Code (341) and the Program Officers' names, last name first, in brackets ([Cohn, Joseph and Perez, Ray]). All full proposals for grants must be submitted through Grants.gov website located at http://www.grants.gov/.

ONR plans to award as follows:

- Phase 1 – up to 4 awards, up to $1.5M each;
- Phase 2 – up to 2 awards, up to $1M each.

The anticipated period of performance for Phase 1 is two years. For Phase 2 the anticipated period of performance is 1 year. Funding decisions are anticipated to be made by **31 October 2011**. Projects awarded as **grants** have an estimated award date of **31 January 2012**. Projects awarded as **contracts** have an estimated award date of **31 March 2012**. Although ONR expects the above described program plan to be executed, ONR reserves the right to make changes.

V. POINTS OF CONTACT

In addition to the points of contact listed in ONR BAA 11-001, the specific points of contact for this announcement are listed below:

Technical Points of Contact:

LCDR Joseph Cohn, PhD joseph.cohn@navy.mil

Dr. Ray Perez, ray.perez@navy.mil

Business Point of Contact:

Mr. Sean Palmer, sean.m.palmer@navy.mil