NATIONAL SCIENCE FOUNDATION
Proposal Abstract

Proposal Title: Convergence Accelerator Phase I (RAISE): Scalable Knowledge
                              Network to Enable Intelligent Textbooks
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The NSF Convergence Accelerator supports team-based, multidisciplinary efforts that address challenges of national importance and show potential for deliverables in the near future.

Properly educating the STEM leaders of tomorrow requires moving beyond knowledge being transmitted from teacher to learner via paper textbooks and lectures. The broader impact and potential social benefit of this Convergence Accelerator Phase 1 project is to launch the Textbook Open Knowledge Network (TOKN). The TOKN project will be executed by a multidisciplinary team of cognitive scientists, machine learning and artificial intelligence engineers, and educators from Rice University's OpenStax and Stanford University who are committed to creating a library of intelligent textbooks, engaging more partners as the project progresses. To begin, this project will build knowledge graphs that capture the complex relationships between educational concepts. A knowledge graph enables artificial intelligence algorithms to provide enhanced and personalized functionality to intelligent textbooks. Consequently, the intelligent textbook can provide more robust courseware functionality (text, videos, simulations, etc.), learning analytics, and personalized tutoring, such as automatically generating summaries of textbook content, generating useful practice exercises for students, providing interactive dialogues with students to help them better understand and master the underlying source material, and more. Integrating this intelligent technology into the full OpenStax free and open library has the potential to impact academic outcomes for millions of students in both secondary and higher education, while significantly advancing the state of education worldwide.

Intelligent textbooks provide an opportunity to facilitate better learning for students. However, they require major investments of time, money, and expertise. An appropriate knowledge graph is at the heart of an intelligent textbook and is often the biggest challenge to intelligent textbook creation due to the need for human subject experts to develop the semantic connectivity of terms and ideas. TOKN aims to develop new, scalable processes and supporting technologies for generating high-quality and extensible knowledge graphs for intelligent textbooks. The proposed research aims to lower both the cost and time required to produce high-quality knowledge graphs. In contrast to using subject matter experts, this project proposes to use a combination of machine learning algorithms and crowdsourcing of knowledge from students. Crowdsourcing will not only provide data for knowledge graphs, but it will also provide an opportunity to evaluate the pedagogical effectiveness of concept mapping on student learning. Phase 1 of this project will include a proof of concept to construct and validate a knowledge graph for one chapter of OpenStax Biology, a free and open-source text used by more than 30% of students in college biology programs. The overarching goal is to eventually apply this approach at scale during Phase 2 to generate knowledge graphs for the entire OpenStax library of 38 general educational textbooks, transforming

them into intelligent open textbooks for society.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.