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A Corporate-Academic Partnership to Deploy Game-based Learning Around the World

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Abstract:

The challenges of the 21st century are complex and systemic in nature, demanding transdisciplinary and collaborative mindsets to solve. However, much of university STEM education still reflects an emphasis on instructor-centered content delivery, through passive lectures and uninspiring lab courses. This approach discourages potential science and engineering talent, disproportionately affecting women and underrepresented minorities. The university of the future likely will be an "experience university", focused on empowering learners to embark on personalized learning pathways. Herein, we present an ongoing partnership between academia and a multinational corporation to produce online gaming experiences to empower students, faculty, and librarians around the world with active learning. The Engineering Academic Challenge (formerly Knovel Academic Challenge) is a five-week game encouraging exploration of National Academy of Engineering (NAE) grand challenge-inspired topics. Each week focused on a new theme, presenting real-world scenarios to provide players with the impetus to "pull" from knowledge discovery platforms to derive the correct answer. Players can also earn microcredentials for certain behaviors in the game, a rising trend in 21st century academic credentialing. The game is co-created by a team of students, an engineering librarian, and a major technical publisher. To date, the two games have impacted over 5000 students in 530 universities worldwide over the past two years. Over eighty percent of players indicated that the game was their first exposure to the NAE grand challenges. Forty percent of players indicated it was their first time using either the Knovel or EngineeringVillage products. Players stated that they i) enjoyed the real-world connection of the game, ii) were exposed to knowledge discovery platforms to accelerate search, and iii) were very likely to use the platforms again in future research and development projects. The future direction of this work is toward a platform for open-ended STEAM challenges created by the community, for the community to empower learners around the world.

Introduction

By 2050, global population is projected to reach ten billion, with 80% of the population living in cities, requiring twice as much energy compared to today's civilization(1). Challenges such as creating an abundance of future of energy, water, and food belong are termed "wicked" problems(2), that require transdisciplinary collaborative approaches to address. However, many structural elements of the modern university(3) (departments, grades, professional disciplines) were established to meet the needs of industry at the dawn of the industrial age, a time period when the average human life expectancy(4) was approximately forty years old and knowledge flowed at a pedestrian pace, compared with today's "4th Age of Information(5)". While the legacy science and engineering curriculum model has produced the talentbase

for tremendous technological advances through the 20th century, many engineering education leaders have recently amplified calls for a transformation of engineering education to embrace complex systems thinking, transdisciplinary collaboration, communication, and social impact[6], producing "a whole new engineer"[7]. Addressing global grand challenges demands a broader reimagining of university experience to meet the needs of the 21st century, just as they did to meet the needs of the industrial age[3]. Universities around the world should be the places to bring structure and context to transdisciplinary knowledge streams, empowering students to become knowledge integrators and creators charged with solving wicked challenges.

In this broader context, we report an ongoing effort between a university and a multinational corporation to create online experiences for students around the world to learn core research skills in context of global grand challenges. Information literacy[8, 9] is a foundational transdisciplinary skillset, arguably the core literacy of the 21st century[10, 11], the ability to extract signal from noise and distinguish truth from fantasy. Passive lecture-based demonstrations of research skill, absent a specific context are rarely a successful pursuit[12, 13]. Absent a clear "real world" connection, students may not grasp the importance of research skills and conventions of knowledge dissemination and generation. Incoming university students tend to overly rely on Google and YouTube, while underutilizing the knowledge discovery platforms accessible through the university library[14-16] to directly access primary literature on emerging knowledge. While Google may be sufficient for high school projects, in postsecondary settings (especially in STEM fields) students encounter difficulty in the face of complex, voluminous information. Librarians and educators have sought new approaches to better reach their students. Some have turned to games, which have demonstrated statistically significant performance improvements over traditional lecture-based approaches[12] in keyword development and citation skills.

Game-based Learning: A Brief Review

Game based learning refers to "the use of game mechanics and experience design to engage and motivate people to achieve their goals"[17]. In STEM fields, games now cover diverse topics ranging from numerical methods[18], algebra[19], electrostatics[20], cell biology[21], protein folding[22], space exploration[23], CAD[3], chemistry[2, 22], pharmaceuticals[24], research methods[25], and entrepreneurship[26]. Digital games are the most engaging and interactive form of media available today, with global reach. The successfully massively multiplayer online game (MMORPG) World of Warcraft has 11 million players, who have cumulatively spent six million years playing the game, a sum equal to the amount of time from the appearance of the earliest upright primates on Earth. Games stretch players to the leading edge of their skills, and encourage self-directed exploration of a virtual world to harvest the information needed to advance to the next level, in an intensive "flow" state[27]. Games exemplify the notion of personalized learning[4], giving individual players freedom to choose different experiences (e.g. quests or tasks)[28] based on their current knowledge

and skills – a freedom seldom found in legacy education settings. Gaming quests involve the formulation of hypothesis, experimentation, and updating these strategies based instant feedback from decisions made, closely paralleling the scientific method. In our view, games will be an important component of addressing calls[28, 29] for inquiry-based research or design active learning experiences from the onset of the university experience. A preponderance of evidence demonstrates that introducing active learning in any form to the classroom environment (e.g. peer-led learning, clickers, reflective discussions, socratic methods, games)[30, 31] significantly improves conceptual understanding while reducing failure rates across disciplines, institutions, and class sizes[31].

Digital games are an exciting opportunity to explore meaningful technology integration to enhance learning experiences. Games can deliver a continuous data-driven view into how learning occurs, at a level not captured in offline, periodic assessments of learning (e.g. exams). However, educational games have been difficult to develop and sustain. The grant funding model produces games that are difficult to sustain, often hosted on individual researcher websites. Furthermore, major game development firms such as Rockstar (the firm behind Grand Theft Auto) do not have the connections in academia or incentive to develop educational games[4], given the lucrative profits from their core products.

Engineering Academic Challenge (EAC)

A team of engineering students and a librarian partnered with information analytics company Elsevier to create a game-based experience to enhance students' research skills, build awareness of grand challenges of civilization, and augment educators' efforts to create active learning experiences. The Engineering Academic Challenge (EAC)[32] and its' former incarnation as the Knovel Academic Challenge[33] have together impacted over 5300 learners in ~530 universities worldwide in the past two years, making it the largest scale implementation of an information-literacy game to the authors' knowledge. The EAC is an experiential layer created atop the EngineeringVillage[34] and Knovel[35] discovery platforms (**Figure 1**). EngineeringVillage indexes the most comprehensive engineering knowledge databases (Compendex and Inspec) with coverage dating back to the 1880s. Complementing EngineeringVillage, Knovel provides access to thousands of ebooks, material properties, interactive equations. EAC questions are designed to provide an interesting impetus for learners to engage in the process of pulling and evaluating relevant information in context of 21st century technical challenges. The scenarios are derived from current dominant trends in science and engineering, such as the future of transport, future of making, cybersecurity, Internet of Things (IoT), synthetic biology, and the push for sustainable energy.

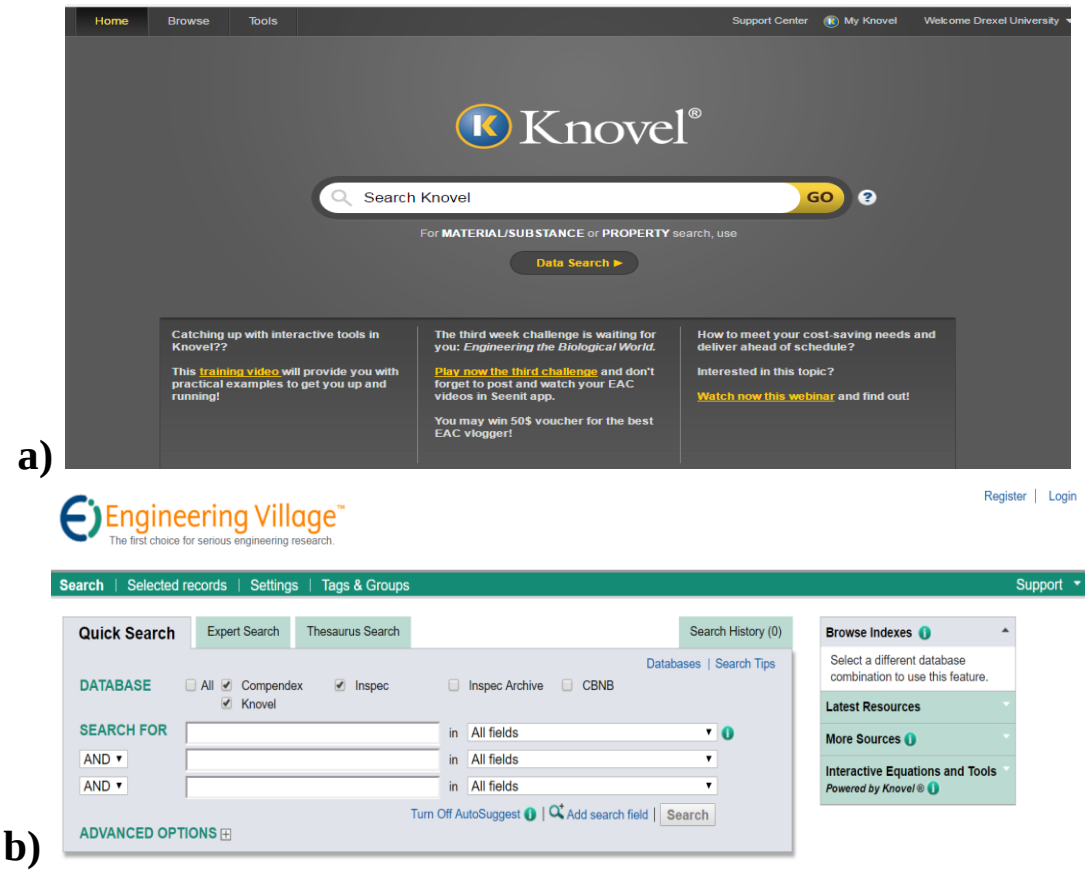

Figure 1: The **a)** Knovel and **b)** EngineeringVillage are complementary knowledge discovery platforms. Knovel provides access to electronic books, material properties, interactive equations whereas EngineeringVillage indexes across twelve engineering databases containing the latest research and intellectual property content. Both platforms are widely used across academia, industry, and government R&D.

Figure 2: The 5 weekly themes explored in the Engineering Academic Challenge, from left-to-right: Energy for a Sustainable Future, Connectivity in the 21st Century, The Future of Making, The Future of Medicine, and the Future of Transportation.

The Engineering Academic Challenge first launched for a five-week period October-November of 2016[32]. Each week's questions revolved around an overarching theme (presented in **Figure 2**), explored through 5 multiple choice questions presented to players. Short video clips to provide richer context were embedded within the game for certain questions. Players had a one-hour time limit to complete each weeks' challenges, earning points for correct answers and earning digital badges for certain gameplay[32] actions. Players could play alone, or opt to play the challenge in teams. In the latter case, there was no requirement for the players to be from the same university. Additionally, the game featured a dynamically updating individual, team, and institutional leaderboard and microcredentialling system (**Figure 3, a-b**).

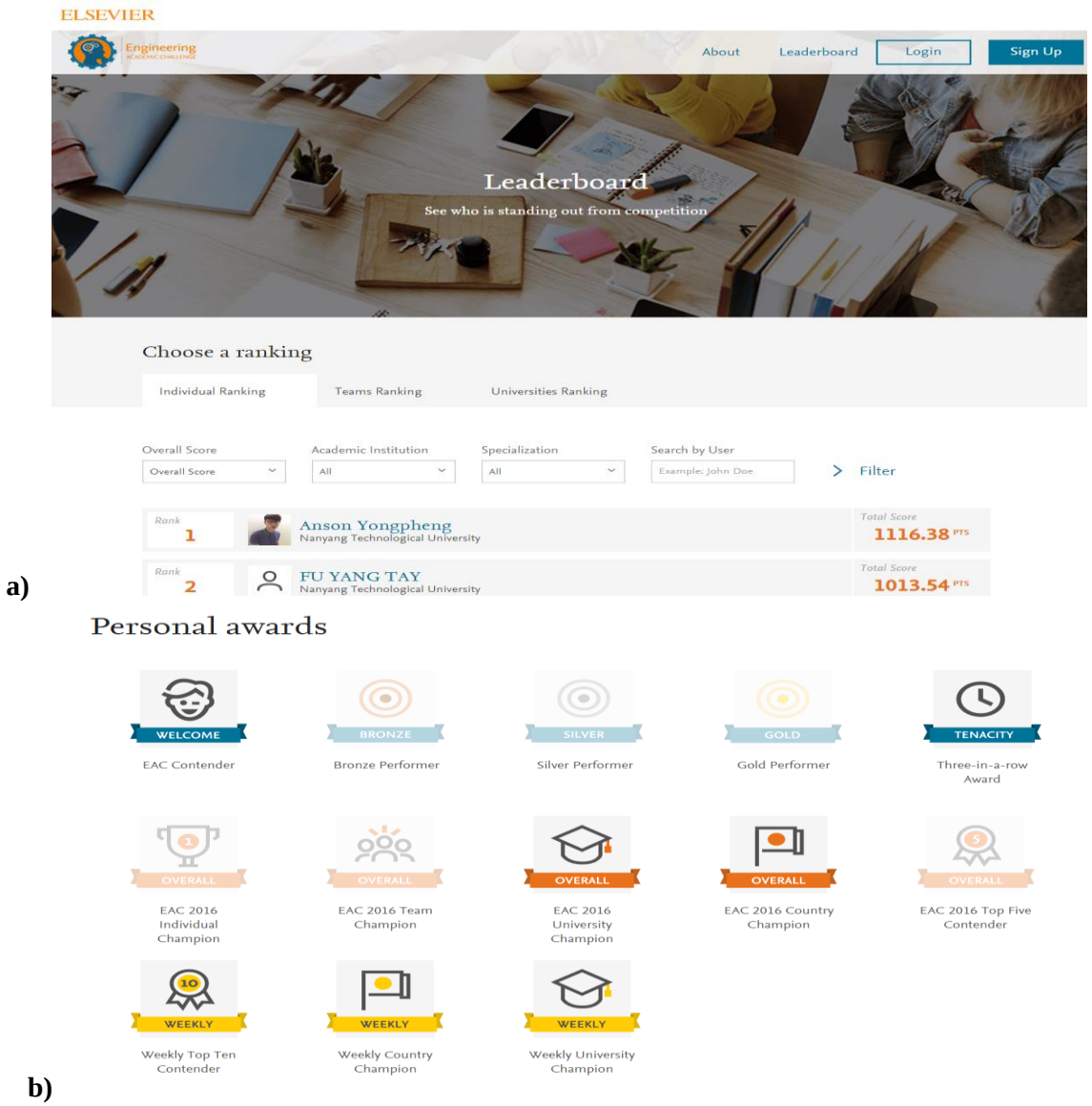

Figure 3: The Engineering Academic Challenge features an **a)** leaderboard displaying scores for individuals, teams, and universities in real-time, and **b)** digital badges (e.g. microcredentials) that students can unlock for certain accomplishments in the game.

On-Campus Engagement

Inspired by hackathons, the EAC development team organized a series of EAC "marathons" on the Drexel campus throughout the five-week game, which were livened with food, giveaways, and prizes to further incentivize participation. The development team also created an educator toolkit with guidelines and materials (e.g. template flyer, email templates, tutorials) to replicate this on-campus engagement strategy across universities globally (**Figure 4**). Universities around the world, United States, China, India, Korea, Australia, Singapore, Malaysia and others adopted this marathon strategy to create shared experiences on their campuses around the game.

These events were structured to create informal learning environments, e.g. "learning for fun"[36]. Approximately 90% of students' time in university is spent outside the classroom in everyday life, work experiences, side projects, research labs, and various extracurricular activities. This "90% time" fosters academic and social integration, which is an essential component of the university experience for retention and persistence[5]. Packer in 2006 called for educators to "… reject the idea that informal and formal learning should remain separated, and instead focus on empowering both spheres through facilitation, collaboration, and openness to learning from one another"[36]. Given the onset of open microcredentialling[37] standards[38, 39] and democratization of tools, the distinction between formal and informal learning will increasingly blur.

Figure 4: Festive on-campus engagement, and excitement surrounding the Engineering Academic Challenge.

Outcomes & Discussion

The EAC encouraged players to explore the EngineeringVillage and Knovel platforms' features such as advanced search filters and material property search to quickly and efficiently extract relevant information. We also invited to players to comment on whether they would use EngineeringVillage and Knovel again in their research or education - a sampling of their testimonials shown in Table 1. Players reported that the tools enable discovery and integration of transdisciplinary knowledge beyond the scope of their normal coursework.

Table 1: Player comments on their experience with the 2016 Engineering Academic Challenge, and likelihood to use the discovery platforms again.

Are you likely to use Knovel or EngineeringVillage again for your research or education?
Yes, Knovel and EngineeringVillage proved to be of great help to me during the Engineering Academic Challenge. Because of the EAC, I got familiar with how to use them and now I can readily use them for help.
It was new and interesting, and not in my textbooks
Yes, I feel that I am more aware of the resources available on both platforms
I will definitely use Knovel and EngineeringVillage in my further studies due to the need for credible academic resources for research references Knovel has exposed me to new areas not covered in my lecture subjects
I will continue to use Knovel and EngineeringVillage because it is a great comprehensive resource for research points
Yes, it's a one stop shop for information I need
Yes, it is reducing the burden of searching for literatures, which would take a long time using conventional search approahes and also it gives authentic results

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Approximately 40% of surveyed players globally (from N=256) reported the game comprised their first experience using either the Knovel or EngineeringVillage platforms, with 17% and 24% reporting they had used EngineeringVillage and Knovel at some point prior to the gaming experience (**Figure 5**). Furthermore, 88% percent of these players indicated their intention to use the platforms again in their coursework or independent research. Additionally, just over 80% of responding players indicated that the EAC was their first exposure to the NAE Grand Challenges. Responses to this same question isolated within an American university also indicated this level of initial unfamiliarity with the grand challenge themes, suggesting that the challenges are not widely discussed in engineering programs. The late NAE president Dr. Charles Vest and other have called for deep integration of the liberal arts with engineering[4, 7, 40], as part of a broader transformation of engineering education. Along this thread, the EAC placed emphasis on transdisciplinary grand challenges to made the game interesting to non-engineering students as well.

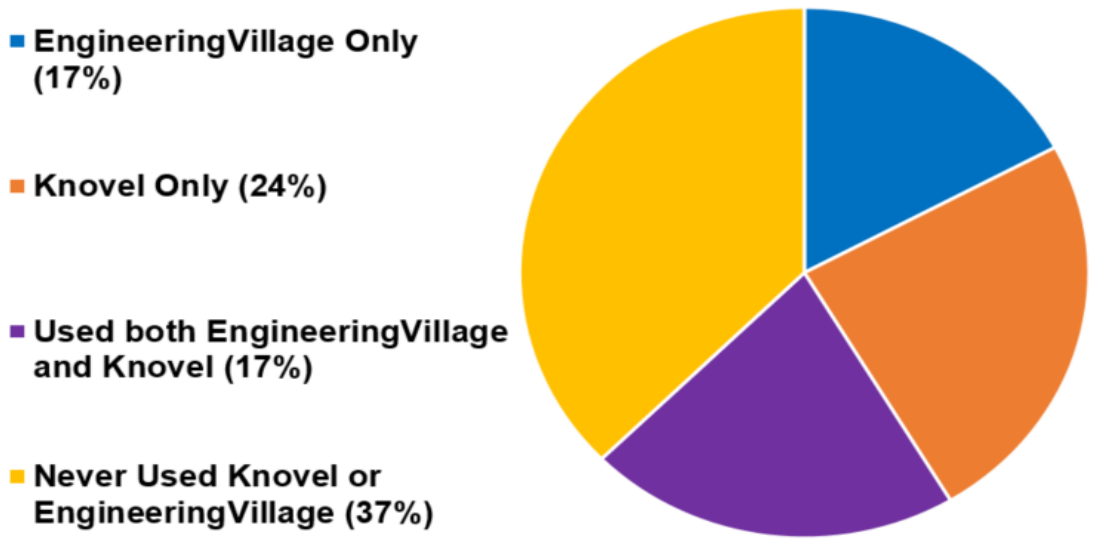

Figure 5: A breakdown of the players' prior experience using the Knovel and EngineeringVillage discovery platforms

Development of Future Learning Experiences

At the time of writing, an international Engineering Academic Challenge focus group of educators and students was created to provide detailed feedback shaping future EAC experiences. In addition to the global multiple choice game with automated scoring, future EAC experiences will include open-ended design challenges formulated by industry. Such challenges would likely be deployed on a regional basis, and be offered more frequently than the twice per year global online game. In addition, the EAC's emphasis on transdisciplinary integration makes it a potential platform for universities to give accepted engineering students (e.g. students between secondary & university education) a fun overview of engineering's role in shaping civilization, to help students envision career "missions". Additionally, future EACs may give educators the option to customize the game according to degree program learning objectives, and seamless integration with learning management systems (LMS) such as Blackboard, to augment courses with game-based modules that promote information search skillsets.

Concluding Remarks & Future Directions

The Engineering Academic Challenge has inspired thousands around the world to engage with primary literature through the EngineeringVillage and Knovel discovery platforms in context of real-world engineering challenges. Through games, educators have a powerful medium to create personalized learning experiences that encourage exploration and "failure" (e.g. iterative learning). In place of test scores, homework, and grades, students can learn through complete challenging quests that encourage deep exploration while earning badges linked to updating digital portfolios. Games alone do not represent a new

university model, but they can play a key role in the broader reimaging of the undergraduate STEM learning experience.

Innovation-driven organizations demand integrative and creative thinkers to formulate solutions to complex, systemic challenges of the 21st century. Corporations and government agencies have vested interest in improving the quality of STEM graduates, given that they form the talentbase needed to solve the complex problems of the 21st century. Corporate-academic partnerships can be multipliers of pedagogical innovations to reach learners around the world, when ecosystems of learners, educators, and employers come together to co-create learning experiences in the cloud, to empower students around the world.

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