"Finding America's Next Generation of Creative Thinkers: An Investigation of Competitions that Challenge High School Students to Embrace the Unknown"

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ABSTRACT

America is built on innovation, and our current education system for high school students is not fostering the creative talent needed to sustain that innovation. Existing efforts to teach and to inspire creativity come in the form of project-based learning inside the classroom and various programs outside the classroom. Benefits in student academic performance, adaptability, and engagement are most profound when students participate in competitions that have open-ended and ambiguous challenges. This paper investigates how three specific student competitions at the middle and high school levels (American Mathematics Competition, Robotics, Debate) foster creativity through difficult math problems, steep engineering constraints, and impromptu rebuttals, respectively. Formalizing student participation in such settings will not only address the lack of creativity but also increase a much-needed sense of belonging among high school students.

1.0 INTRODUCTION

The United States has long been recognized as a hub of innovation and technological advancement, but how long can we keep that title? Since World War II, the US has built a reputation on the strength of its science and engineering graduate education (Teitelbaum). As the foundation of our evolution, this education system has been essential in producing technological advancements that boost economic growth, job creation, and standard of living. The intellectual contributions of our rising generation, especially from university and high school students, are the leading factor in maintaining this title. These students, often at the forefront of research and development in their academic institutions as they seek advanced degrees, are increasingly contributing to the pool of intellectual property (IP), which encompasses a wide range of disciplines, indicating a diverse and multidisciplinary approach to innovation (Babina).

The educational background of domestic patent recipients is notably credited towards higher education, with nearly 60% holding bachelor's degrees during the period of 2013 to 2017 (Fleming). Within this group, a significant 66% had degrees in STEM fields. Graduate degree holders, including those with master's (23%) and doctoral degrees (18%), are prominent in patent acquisition, accounting for 41% of U.S. patents (Fleming). This trend is further evidenced in university settings, where graduate students and postdocs (postdoctoral researchers who have completed their doctoral studies and are engaging in further training to enhance their professional skills) are predominantly responsible for university commercialization activities (Babina). The Bayh-Dole Act of 1980 plays a crucial role here, incentivizing universities to patent their research findings, thereby contributing to U.S. and global competitiveness.

The United States has benefited immensely from the contributions of international scholars and students, adding even more diversity and depth to its innovation ecosystem. Increasingly, the source of key innovators has come from non-domestic talent, with immigrants making up 16% of U.S. inventors and being responsible for 23% of patents issued between 1990 and 2016 (Bernstein). Adding to the significance of immigrants to U.S. innovation, it's notable that these foreign-born inventors are numerous and highly impactful (Berstein). Their patents were slightly more influential, as indicated by the number of citations each received over three years, a key measure of patent quality and utility (Chen).

If a growing number of innovators are born in international countries, where does that leave the U.S. in terms of a talent pipeline? How can the U.S. continue to hold its title of the hub of innovation if all of its innovation comes from foreign minds? This review article aims to

highlight current efforts to strengthen our domestic source of creative thinkers and recommends the next steps in achieving such outcomes.

1.1 Current trends in the American education system that limit student creativity and innovation.

The very foundation of the American education system, from kindergarten through 12th grade, is failing students when it comes to nurturing creativity and innovation. Journalist and chronicler of the rise of Silicon Valley, Po Bronson points to data showing “American creativity scores are falling... particularly for younger children in America—from kindergarten through sixth grade” (Bronson). This decline seems to be directly correlated to the overwhelming focus on standardized testing and rote memorization that currently dominates the education system in public schools. “There is no concerted effort to nurture the creativity of all children” amidst the focus on meeting curriculum standards that public schools are required to comply with (Bronson). Schools are so fixated on meeting requirements in order to receive funding that they compromise the quality of education for the students.

Psychologist Mark Runco's research at the University of Georgia has revealed an intriguing aspect of creativity in educational settings. His findings indicate that “significantly more creativity was reportedly displayed outside rather than in school” (Runco). The restrictive, structured environment in school appears to actively dampen the creative talents and potential that students possess. This is obvious in terms of engagement levels in the classroom versus creative pursuits and expressions outside of the classroom. Runco concluded, students have innate “creative potential. As evidenced by their creative activities and achievements outside of school, but these potentials are not displayed when they are in school, perhaps because usually there is more structure and restrictions in school” (Runco). While students possess creativity, the strict requirements of tasks presented in the classroom leave little room for personal interpretation and thus little room for creative thinking.

This rigid focus on standardized curriculum, rote memorization, and high-stakes testing is actively stifling creativity in students by prioritizing the passive absorption of information over encouraging original thinking, exploring interests, and innovating (Bronson). The result of this is that “As school stuffs more complex information into their heads, kids get overloaded, and creativity suffers” (Bronson). Overwhelmed students faced with the relentless pace of absorbing and regurgitating facts lose the capacity to develop their own insights and ideas on the material. This unhealthy mindset of studying through memorization rather than interest essentially de-emphasizes education as a whole. What makes this crisis even more alarming is that advanced graduate programs are linked to increased innovation, competitiveness and economic growth for the nation (Leming). But realizing these benefits over the long term requires a more relaxed learning environment, one that is able to nurture creativity, curiosity and insight rather than de-emphasize the unknown and therefore failure. As Leming summarizes regarding graduate-level education, “sustaining quality training programs, retaining STEM experts, allocating research resources wisely, and applying new technical knowledge in translatable ways is equally vital” for ongoing innovation (Leming).

The emphasis on standardized testing and rigid curriculum in early education is failing to cultivate the types of creative minds that drive progress. Students overloaded with rote memorization are not quite equipped to solve unstructured problems they/humanity are likely to encounter in the future. Synthesizing information into original ideas and pioneering innovation in response to new crises are essential for the development and survival of humanity. America’s

traditional leadership in creativity and innovation is now threatened by this lack of emphasis on nurturing free-thinking students in the K-12 education system. Truly addressing this crisis would require recognizing the failures of the current system and taking steps in order to foster creativity and insight at every stage of learning. The passive, restrictive environment in most public schools actively inhibits the development of knowledge and capabilities that the modern economy increasingly demands. Currently, the students graduating from the K-12 learning system are not equipped to evolve alongside the face paced world of the present. How can we have robots/AI adapting to unforeseen problems when humanity can't do the same?

1.2 Fostering innovation in 21st Century through educational programs

Fostering innovation relies significantly on educational reforms and programs that emphasize creativity and critical thinking. Classroom training in creativity, mainly through experiential techniques, can greatly enhance students' critical thinking abilities and group skills, preparing them for careers in entrepreneurship/innovation (Shaheen). Integrating art and creativity elements into the STEM curriculum, evolving it into STEAM (Science, Technology, Engineering, Arts, and Mathematics) programs, equips students with advanced problem-solving skills and technology fluency necessary to adapt to the future of job markets (Chicas). Looking at existing examples, nations like Singapore, Finland, and South Korea demonstrate the impact of education investment reforms with their increased innovation capacity and global competitiveness (Han). Such reforms are not just about enhancing academic performance, but about shaping a workforce capable of innovation and adaptability in a rapidly changing world. This approach includes both project-based learning within classrooms and reinforcement learning—a combination of scholastic and practical experiences—alongside various extracurricular programs that further nurture creativity and innovation outside the traditional classroom setting (Shaheen).

Programs outside the classroom that emphasize competition have taken the lead in fostering innovation and creativity by nurturing high-ability students. These competitions, such as the American Mathematics Competition (AMC), team-based robotics and high school debate, serve not only as platforms for talent identification and development but also as catalysts for enhancing the educational process itself. The common theme in all these programs is ambiguity. Open-ended problems and challenges allow for students to really flourish as individuals, thereby encouraging students to shape their own education rather than having a teacher shape it for them. The benefits in student academic performance, intellectual adaptability, and learning engagement are profound when more is demanded of them. What follows is a summary of the literature on these programs as case studies for fostering creativity.

2.0 Case Study #1: The American Mathematics Competition

Mathematics competitions such as the American Mathematics Competition (AMC), play a crucial role in identifying and fostering high-ability mathematical/creative thinking students. These benefits impact not only individual participants, but also educational institutions, and the field of education itself. The integral role of mathematics competitions like the AMC in nurturing high-ability students in mathematics and creative thinking benefits individuals and enhances educational systems.

2.1 Identification and Fostering of Talent. Competitions are crucial in identifying students with exceptional ability of any kind. As noted by Kenderov, "Competitions help identify students with higher abilities in mathematics [and] . . . develop their talents and to seek

professional realization in science (Kenderov)." When competing against classmates, friends, and peers, students are pressured to perform to the best of their ability, helping educational institutions to see the full extent of their students abilities. In comparison students that only seek education in the classroom often lack the challenge needed to unlock their true potential.

2.2 Positive Impact for Schools. The influence of competitions extend beyond just individual participants and actually benefits academic institutions as well. By spectating competitions and study skills that challenge students, teachers can learn improved teaching methods, and have a heightened interest among students that desire to be challenged. Schools can take advantage of this by teaching skills and introducing problems that leave students searching for an answer rather than being handed it.

2.3 Benefits For All. The advantages of mathematics competitions and competitions in general is the rewards are not limited to just the winners. As Kenderov points out, "What frequently escapes public attention . . . is the fact that the other, 'non-winner' participants, also gain a lot" (Kenderov). Even without standing out due to exceptional capabilities, the non-winners gain knowledge that helps strengthen their individual skills. Studying for a topic that's not your strong suit can show you the best way to learn which is unique for every individual. By taking the competitions and thus preparing for them, students gain the skills needed in order to excel in other aspects of their life whether it be another academic topic, sports, or social interactions (Kenderov).

2.4 Development of future mathematics curriculum. Through the ever changing nature of mathematics and mathematical competitions specifically, this guarantees the continuity and advancement of difficult mathematical knowledge that best suits our modern world. “A significant part of the classical mathematical heritage known as 'Elementary Mathematics' is preserved, kept alive and developed through the network of competitions and competition-related activities,” which also allows for the adaptation of new mathematical concepts that best fit our world today while still building on the fundamental basics (elementary mathematics) taught for centuries (Kenderov).

2.5 Preparation for future. Similarly to the point that Kenderov makes about the benefits of competitions for all is reinforced by Susnea who states, “Competition based learning (CBL) is beneficial not only for the relatively small group of winners – the other, non-winner participants have also a lot to gain as preparation for future real-life competitions" (Susnea). Competitions with settings similar to the AMC focus on reactive thinking and prepare students with a set of skills that enables them to think without telling them what to think. Other than learning a set of basic fundamentals like notations and strategies, the only real preparation is through repetition. Requiring students to prepare by engaging in difficult open-ended problems and taking tests multiple times after only receiving scores like a 4 out of 25 emphasizes the dedication it takes to reach any goal in life. After receiving a low/undesirable score on the AMC, students must learn to take away from that experience and take another test, often receiving the same score and sometimes even a lower one.

2.6 Adapting to future challenges: the evolving nature of competitive mathematics. The nature of competitions inspires subsequent competitions to implement practices learned from the prior (Losada). Once again, it's important to understand the flexibility of competitions as an educational opportunity. They allow for tests to adapt from one another and can change based on the educational standard of the ever evolving world. Seen each year, the AMC continues to grow in difficulty which emphasizes the need for more creative/reactive thinkers in order to prepare humanity for AI and all the complications that come with it. Modern challenges

might include unforeseen breakthroughs or challenges in AI that need fast solutions such as information hacking that is inevitably going to evolve along with AI.

2.7 Boosting confidence and growth: the psychological benefits of competitions. Losada also emphasizes that competitions can be particularly beneficial in boosting the self-confidence of students, a quality that is often lacking in newer generations. Competitions address the problem by forcing students to see their own true potential in competing thus giving them a sense of confidence (Losada). Even the students that don't excel at their current competition can learn from the process in which they competed, taking their newfound experiences into a different field in which they excel. Everyone has a competitive side, emerging when seeking to prove oneself which activates the true potential of a student that is required for great success (Susnea). Through competition, students can practice this mentality and hone it in order to use it in other aspects of their lives.

3.0 Case Study #2: National Robotics Competitions

Robotics in education has been recognized as a tool for enhancing student learning, especially in the realm of STEM (Science, Technology, Engineering, and Mathematics). Robotics, due to its multifaceted nature and its ability to develop cognitive and social skills, has recently increased in popularity among students and teachers (Afari & Khine). A key aspect of educational robotics is the nature of its interdisciplinary approach, which includes mathematics, physics, design, innovation, electronics, computer science, programming, and psychology (Afari & Khine). This multi-educational aspect not only diversifies learning, something essentially for young adults, but also prepares students for the complexities needed in real world problems and occupations.

Robotics programs such as the VEX Robotics Competition, FIRST Robotics Competition, FIRST Tech Challenge, and FIRST Lego League are available throughout the US and the world. Started in 2007, VEX programs in 2022 involved over 400,000 students in grades 4-12, and about 30,000 students from more than 50 countries participated in their annual robotics world championships (REC). Since 1989, FIRST Robotics programs have seen more than 2.5 million student participants from 100 countries, and approximately 668,000 students participated in the 2022-2023 season ("At-a-Glance"). Its programs are organized by age group, with the challenges and technical demands increasing in difficulty as the student ages. In 2022, FIRST Robotics had its annual international competition with participation from 3,225 teams, including more than 80,000 students and 25,000 mentors from over 26 different countries ("At-a-Glance"). This level of participation for these programs shows this field's popularity and international importance.

3.1 Reinforcement learning in robotics. Another key aspect of robotics is its relation to the constructivist theory of learning, a type of learning that emphasizes learning through hands-on involvement through things/activities that hold personal significance (Eguchi). The nature of robotics forces students to innovate, which almost always stems from a place of need. When someone desires something that is not given, they are inclined to seek it out themselves, this is the key educational aspect of robotics. Educational planners globally are recognizing the potential of robotics, leading to its semi-recent integration in school curricula to offer students of all ages the opportunity to learn with robots (Afari & Khine). Programs like RoboCupJunior, for instance, stand out for their effective promotion of STEM learning, as evidenced by studies that highlight RoboCupJunior as an influential educational robotics program (Eguchi). These

programs provide project-based and goal-oriented learning experiences with lasting impacts on student motivation and interest in STEM fields (Eguchi).

3.2 Statistical influence of robotics on education. The influence of robotics education on student lives is also noteworthy. According to Melchior, participation in robotics programs like FIRST Robotics is associated with higher rates of high school graduation and college attendance (99% of FIRST alumni in the study graduated high school compared to 65% nationally, and 89% attended college compared to 62% nationally). There's also a notable increase in the pursuit of STEM careers among these students, with a significant percentage majoring in engineering in college (41% of FIRST alumni majored in engineering about 7 times the national average of 6%) – far exceeding national averages. This trend is particularly encouraging for female and minority students, who have shown higher rates of pursuing engineering majors compared to national averages (Melchior).

3.3 Rationale for implementing robotics programs. Educational robotics doesn't just enhance technical skills; it also fosters critical thinking and problem-solving abilities. Studies cited repeatedly by authors like Okita, Kim, and Mohr-Schroeder demonstrate the positive effects of robotics on students' engagement in STEM, proportional reasoning skills, and understanding of mathematics and physics. Besides its benefits, robotics is also incredibly user-friendly and has enabled teachers, even those without strong backgrounds in robotics or programming, to incorporate robotics/STEM learning into their classrooms (Oppliger). The popularity of the subject has led to an increase in online material, making it easy and cost-effective for scholastic programs to reap the benefits of robotic education on students.

4.0 Case Study #3: Debate Competitions

Debate fosters critical thinking, reasoning skills, and social-emotional skills. Students who engage in debate are constantly challenged to explore open-ended questions, which encourage them to think beyond mere surface-level education often required by schools (Bauschard & Rao). This leads students to deal with diverse information when researching as well as forces them to create sound logical arguments to the common parent which sharpens their flow of thinking (Bauschard & Rao). By evaluating different aspects of an issue, students in debate learn to make informed, rational decisions, a critical skill that benefits all students beyond the educational surface.

4.1 New perspectives and social-emotional learning. Debate also plays a crucial role in fostering empathy and social tolerance in young students (Bauschard & Rao). As students delve into their side of an argument (which is assigned to them), students will often find themselves defending a side that is not their own, and attacking a side which is. This leads students to understand the perspective of opposing viewpoints beyond just debate. This promotes empathy and understanding, an important aspect of collaboration and creating more interconnected communities (Bauschard & Rao). Debate also de-emphasizes verbal aggression, something that often takes away points in a competition. This promotes more civilized arguments which is something not really seen in the modern political world today (Bauschard & Rao).

One of the key benefits of competitions in general, as pointed out earlier, is addressing the lack of confidence in younger generations (Losada). Debate perfectly answers this issue as the main aspect of debate is persuasiveness. Participants must be 100% confident in themselves and in their argument in order to convince someone else to believe in their points (Parcher). This deals with both preparation and confidence in one's own skills. Students often

deal with 20+ hours of preparation each week (Bauschard & Rao) in order to develop their argument and combat counter arguments. It's clear that if both sides of a debate arrive this prepared, the decision comes down to which of the participants is more persuasive and cunning (Parcher). In the opening both students must have utmost confidence in their argument which is often a prerequisite to performing in high level debate. Once the debate enters a more argumentative aspect, students must absorb information fast, decide on a point of attack, and narrow in on the weak aspects of their opponents argument. Students back out of an attack as that shows lack of confidence, thus proving their opponents' arguments are flawless.

4.2 Skills developed through competition-oriented debate programs. Critical thinking, communication, and performance are all academic benefits that once again are exercised in debate. Students who participate in debate tend to perform better academically, as the skills acquired are transferable to various academic disciplines and learning situations (Bauschard & Rao). The nature of debate, which requires a variety of skills including but not limited to, economics, philosophy, and political science. This grants students a more holistic and modernized education rather than the traditional math, english, history, and science as taught in schools (Bauschard & Rao).

The nature of discussing varying political and economic issues around the world often leads students to heavily research beforehand. This exercises a number of academic practices crucial to modern education yet not taught in schools (Hogan). First is independent research. Schools often include small aspects of research in classes like history, yet their research is guided. In class students are given a website, sometimes a link and asked to essentially translate the source online into a doc. In debate students must independently find sources, consider whether or not they are trustworthy/verified, and turn those sources into well flowing debates that both support their points and attack the other. Forcing students to learn research skills is a crucial part of adult life which requires humans to find solutions to their own problems (Hogan).

Another benefit of debate for highschoolers is that it’s preparation for the future. Eldred emphasizes that effective communication is a highly sought-after skill across various fields. Employers prioritize oral communication skills in potential employees. This is where debate, with its focus on audience adaptation, clear speech, and logical persuasion, excels. Debate encourages debaters to engage their audience with eye contact, an open body position, and varied vocal delivery (The Triangle Method). Such skills are essential in the real world, where the majority of message meaning is often conveyed nonverbally.

5.0 Recommendations

In the wake of the pandemic's profound impact on education, now is a better time than any to implement these educational programs. The pandemic has, without a doubt, brought trauma, loss of resources, and unequal impacts on underserved communities (Kuhfeld). However, the shift to online learning comes with an opportunity to overcome geographical and socioeconomic limitations, making these programs more accessible to a diverse student population. The timing for starting or enhancing these programs is perfect, as they not only offer a solution to the intellectual and social isolation caused by the pandemic but also equip students with critical skills needed in an increasingly digital and interconnected world. Implementing these competition-oriented programs offers numerous benefits, fostering important life skills such as effective communication, critical thinking, and confidence in working collaboratively.

Implementing now is an investment in students that goes beyond academic achievement, by preparing students for future challenges in higher education and their careers.

5.1 Implementing the American Mathematics Competition (AMC). This is by far the hardest program to implement due to the high educational requirement to teach the subject as well as minimal online resources that provide curriculum. Team fees can cost around $10-30 per student combined with mentor costs, usually around $1500-3000 per mentor. Given the costs associated with team fees and mentor expenses for implementing AMC-level educational programs, schools should consider sponsors from local businesses/academic programs or explore other reinforcement learning implementations listed below.

However, if funding is not an issue, a structured approach is needed in order to have a successful implementation of AMC mathematics. Firstly, awareness about the competition should be increased through informational sessions and promotional activities, ensuring students understand the benefits and opportunities it offers. Schools should then provide resources for preparation, such as access to past AMC papers and problem-solving workshops. This can be facilitated by math clubs or dedicated AMC preparation groups patterned after programs like UCI Math Community Educational Outreach Program (UCI Math CEO) or Los Angeles Math Circle (LAMC), both of which aim to extend the influence of open-ended mathematics to the general public (MAA & Santillanc).

Moreover, it's crucial to involve mathematics teachers in the process, enabling them to integrate AMC-style problems into their regular curriculum, which can help students adapt to the competition's format and difficulty. Collaboration with local universities is also an incredibly helpful option as it can sometimes fulfill the high education requirement in order to teach the subject. Finally, establishing a supportive environment that encourages participation and celebrates effort, regardless of winning, is essential for the sustainable success of the AMC program. A reminder that the AMC 8,10, and 12 are incredibly difficult tests, often yielding a score of 6.13/25 or a 24.52%. Results like these will be new to a majority of students and it's important for low scores to not hamper their future participation. Participating in the AMC will nurture students' critical thinking and problem-solving skills, providing them with a valuable foundation for academic success and future endeavors.

5.2 Implementing High School Robotics Programs. For the effective implementation of high school robotics programs, a multi-faceted approach is necessary. Initially, securing funding and resources is crucial. Unlike AMC, online resources are incredibly abundant; however, the materials required to source a robotics team is quite expensive. Programs at the elementary and middle school levels start around $1500 (FIRST Lego League) and progress to $5000 (FIRST Tech Challenge) to $25,000 (FIRST Robotics Competition) per season. These costs could be tackled through sponsorships from local businesses, technology firms, educational grants, or school fundraisers.

Next, schools should focus on building a team of enthusiastic teachers and mentors, possibly including professionals from the field of robotics, to guide and inspire students. Hands-on workshops and regular team meetings are vital for practical experience. Schools should also create opportunities for students to showcase their work, such as internal competitions or exhibitions, which can foster a sense of community and teamwork. This is important as showcasing work to the local community can bring in more attention which means more resources and participation. Moreover, integrating robotics into the existing curriculum, even at a basic level, can pique interest across the student body.

Networking with other schools to share resources and experiences can also enhance the program's effectiveness. Robotics often requires the help of a big part of the community which often leads to the community's role in the program. This could not only prove to be beneficial for students and their futures, but also for the schools and families nearby.

5.3 Implementing High School Debate Programs. Implementing a debate program in high schools, similar to the previously stated programs, can be a challenging but invaluable addition to the educational experience. While they may not have the high technical requirements of the AMC and robotics, debate programs likewise require careful planning and resource allocation. Firstly, the cost of establishing a debate team can vary, but schools should anticipate expenses varying from $10,000-20,000 on entry fees, judge fees, and coaching fees (Debateus). These costs can be offset by seeking sponsorships from local businesses, educational institutions, or school fundraising efforts.

Awareness and interest in the debate program can be raised through informational sessions and promotional activities, highlighting the skills and opportunities debate offers, such as enhanced critical thinking, public speaking, and research skills. Schools should provide resources for training and practice, including access to debate materials, workshops, and experienced mentors. Collaborations with local universities or debate organizations can offer additional support and expertise.

Creating a supportive and inclusive environment is crucial. Students should feel encouraged to participate regardless of their skill level, and efforts should be made to ensure that all interested students have the opportunity to join. Finally, it's essential to manage expectations. Debate competitions can be challenging, and students will often face competing students with years of experience. Emphasizing learning and growth over winning is key to maintaining student engagement and enthusiasm.

Conclusion

Competitions like the American Mathematics Competition, Robotics, and Debate foster innovation and creativity rarely found inside classrooms. These platforms not only challenge and nurture young minds but also contribute significantly to their academic and personal development. Emphasizing the need for more real-world applications and creative problem-solving in education, this paper advocates for integrating such dynamic and engaging learning experiences into the curriculum to prepare students for future challenges and maintain America's status as a hub of innovation.

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