The Use of Engineering Design Projects for Student Understanding of Engineering's Societal Impact and Global Responsibility

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Abstract – ABET, as part of its expected program outcomes, states that programs must demonstrate that their students have the education to "understand the impact of engineering solutions in a global, economic, environmental, and societal context." Many programs, however, find it difficult to address these expected outcomes, especially the roles and impact of global and societal contexts because they find the terms vague and ill defined. This paper addresses this concern by first defining what is meant by "societal" and "global" context as they apply to engineering applications; second, by providing an introduction of how these issues are presently being addressed by the engineering education community; and third, by describing how students of four types of University of Tennessee at Chattanooga (UTC) student projects – industry supported, foundation supported , contest based and research based – are introduced to and experience societal and global context applications.

Keywords: societal impact; global context; global responsibility

INTRODUCTION

The Engineering program at the University of Tennessee at Chattanooga (UTC) is composed of Civil, Chemical, Environmental, Electrical, Mechanical, and Industrial emphases, and offers both a freshman and a combined junior/senior interdisciplinary design experience. Both experiences require students to participate in customer sponsored projects. However, the customers and the ultimate goals of the projects vary. Some projects are supported by a grant from the Tennessee Department of Education that focuses on providing or improving assistive technology for young children. Other projects support local industry sponsored projects. Still other projects are sponsored by the college or faculty in the college and provide either specific products for faculty or large products for regional and national competitions or support faculty research. These projects have the usual expected outcomes for design projects. One of the expected outcomes is that students be introduced to and experience the impact of societal concerns and global issues on engineering decision making. But, due to the variation of project types, this is not necessarily an outcome that is easy to measure. What is being questioned is whether all students are being provided opportunities to address this outcome.

To address this question, this paper investigates (1) what the engineering community defines as societal and global concerns and (2) how the engineering education community presently addresses these issues in their programs. The paper then reflects on how well the UTC projects address the expected outcome in relation to present understanding of societal and global issues.

PRESENT UNDERSTANDING OF SOCIETAL AND GLOBAL CONCERNS

ABET Engineering Criteria 2000 includes in its list of course outcomes that students should receive the broad education necessary to understand the impact of engineering solutions in a global and societal context [1]**.** This appears to be an important and reasonable expected outcome of our engineering programs. However, ABET does

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not state how the programs should define or interpret the terms "global context" and "societal context." These concepts are interpreted in varying ways depending on how the program wants to address the outcome.

Many programs find it difficult to separate the definition of societal contexts within the realm of global application. This is true for even those studying the need to address these issues in the engineering curriculum. For example, the National Academy of Engineering of the National Academies states that the aging U.S. population makes greater demands on the health care system, heightens labor force tensions, and increases political instability – all societal issues. But it also identifies an opposing trend in developing countries that has a global impact – more than 50 percent of the world's population could be less than 18 years old in 2020 [11].

In light of the above, the following tries to define both societal and global contexts as they may be used to address the ABET outcome as well as provides a few examples of how they are being addressed in engineering and/or technology programs in the U.S.

Societal Contexts

The present engineering education literature does not provide much background on defining "societal context." In Mansfield's paper "Gauging Societal Concerns," which addresses assessing risk for decision making, Mansfield defines a societal concern as a "collective subjective measure of individuals' concern within society" [Mansfield, 9]. He continues and states that the subjective measure is a perceived level of risk that creates the societal concern. Tomlinson adds that societal concerns or problems, especially those that are "world" problems, are large and complex and difficult to model in traditional ways. His suggestion is to model them using a suite of smaller simple models that interrelate [Tomlinson, 17]. Richardson and Kostyniuk use another method to include societal issues in transportation decision making. They recognize that the public drives societal issues so they use the public participation process based on the multiorganization decision analysis (MODA) method to collect people's views and ensure society is involved in the decision analysis [Richardson, 13].

The National Academy of Engineering recognizes that societal concerns are not easy to address due to their complexity. However, they believe that engineers must learn to recognize the role of societal concerns on design and manufacturing because it is not only the technical challenges that drive the design and decision processes, but the legal, market, political, environmental, health, safety, economic, etc. issues may drive the process as well [11].

Sample Initiatives

Some engineering programs have selected a specific societal concern to emphasize when addressing a course project or decision making topic. For example Handy et al has integrated sustainability and green manufacturing topics into a manufacturing processes course [5]. The specific societal issue is human health impact and it is their belief that integrating environmental sustainability into the curriculum addresses the role of engineering stewardship. They have embedded the topic in the discussions of various manufacturing processes and have included questions on exams to ensure that students are not only introduced to the topic but must try to ingrain the concepts. Other programs address a societal concern through the application of a design project. Daniels et al have IT students improve a situation in a hospital as a way of introducing them to the impact of IT on society. This relationship is easy for students to recognize because they see applications in a hospital as activities that may benefit society [3]. Service learning projects, those that apply academic principles to service a specific community population, are another means some programs use to introduce students to the relationship between engineering and social issues [7]. These projects challenge students to communicate within and to understand societal conditions unfamiliar to them.

Outcomes of Initiatives

Some programs are finding that projects that emphasize community and social impact are attracting female engineering students. There is evidence that having a positive impact on others' lives is a major factor in career choice for females and some under-represented groups. For example, 25 percent of the participants in the Engineering Projects in Community Service (EPICS) program at Purdue University have been women [Coyle, 2]. This program creates a long-team relationship between the local community not-for-profit organizations (partners) and engineering students (teams of 10 to 20 students across the four academic years) to solve the partner's technology-based problems.

Global Contexts

Compared to the literature available on addressing societal issues there is much literature and recent conference discussion devoted to defining ways to introduce engineering students to global issues. Academics are specifically interested in the need for global understanding. Schnell advises that it is the non-technical skills such as learned methodologies and relationship practices as well as global perspectives that differentiate one candidate from others when applying for a technical position [15]. Kellogg et al. support this assertion. They recognize that employers of engineers are expecting engineering graduates to enter the work place with understanding of the skills needed for today's global environment [7].

But what is this global environment? Some authors identify the global environment as the global economy though they do not further define what is meant by "economy" or "global economy." Kellogg et al. do state that understanding of the global economy requires students to have knowledge of international organizational behavior and management. [Kellogg, 7] They also state that to operate in a global economy graduates must be more creative in their thinking skills. Shuman et al. suggest that one means of providing students the creative thinking skills needed to deal with challenges brought by "globalization" is a liberal-arts-based education [Shuman, 16]. The theory is that a liberal-arts-based education teaches students to (1) recognize and manage the political elements of the work environment and (2) handle and value the sometimes ambiguous perspectives of others. In addition, the liberal-arts-based education will help engineering students understand that engineering solutions transcend international boundaries. [Shuman, 16] Such crossings include the distribution of the product as well as the consequences of resource exhaustion and process pollution.

Downey et al. offer that addressing the global environment means one is addressing working with different cultures. An engineering student considering the global environment should have as a learning objective to gain "global competency" – to learn to work effectively with people who define and solve problems differently. [Downey, 4] This objective is most often met through obtaining an appreciation for other cultures and developing a multicultural perspective. However, what makes this objective difficult is that it is increasingly difficult, as the world "globalizes," to identify people as members of specific cultures. This is because people often have responsibilities that place them in more than one country. The objective is also difficult because students, as well as those in industry, have a tendency to minimize the differences between cultures and to focus on the similarities. [Downey, 4] Focusing on similarities does not allow us to recognize and appreciate how people educated outside of the U.S. view and solve problems. Engineers need to value differing strategies for defining and solving problems to work in the global economy. Thus they need to recognize that problems can be solved in more than one way.

Sample Initiatives

Some engineering programs address gaining "global competency" through a team or individual project that involves international experience. The University of Rhode Island's (URI) International Engineering Program combines an engineering degree with a degree in a language to prepare students for at least one term of study in a country where they must use both their language and engineering skills. Another program, at Worcester Polytechnic Institute, allows student teams to complete their capstone design requirement by addressing real-world problems of an unfamiliar culture while immersed in that culture for at least a semester. The students work with the sponsoring organization as if they were supporting a project in the U.S. and present a final formal written report and oral presentation.

However, only a small percentage of American engineering students take advantage of a semester or more of an international study abroad opportunity [Hansen, 6]. Many engineering students can not leave present work responsibilities to go abroad for a semester. Also, many engineering programs are so structured that studying one semester abroad can result in an additional year of study for the student at the home institution. Thus some programs make use of short term international experiences over a student's break or of virtual international teaming or collaboration. One such program is a short term study abroad experience the University of Illinois (UIUC) Agricultural and Biological Engineering students participate in with South African engineering students. This program combines students from the University of KwaZulu-Nata (UKZN) in South Africa with the UIUC students on a mutually selected capstone design project. While at their home institutions, the team members communicate through e-mail to define project goals and tasks. The projects are then completed during a four week intensive visit to the host institution and country. A similar opportunity has been developed by the international relations group of

COPEC – Council of Researches in Education and Sciences. This program provides students and faculty of interested Universities the experience to interact with Brazilian universities and enterprises [Rocha Brito, 14].

Some engineering programs address the "global competency" need by developing an innovative curriculum or embedding global content in a course. At Central Connecticut State University they discuss and compare U.S. and international standards, ISO and ANSI, and their impact in the Geometric Dimensioning and Tolerancing course [Prusak, 12]. The engineering program at South Dakota School of Mines & Technology has been revised to develop complex thinking skills because it is understood that these skills are what is required to perform well in today's global economy [Kellogg, 7]. However, the most popular method of embedding global content in the curriculum is through introducing more design experiences that emphasize open-ended problem solving and involve industry partnerships. It is believed that the "open-ended" emphasis and the industry connection aids in introducing global initiatives and impact.

Outcomes of Initiatives

Study abroad or international collaboration experiences broaden students' global competency in a number of ways. First, U.S. students experience applying their knowledge to solve problems different from those they find in their local environment or may be expected to solve elsewhere in the U.S. [Hansen, 6] Also, students, through research or direct experience, learn about another country and its living and employment environment. But overall, students learn to value problem solving strategies that differ from their own [Downey, 4]

Interestingly, engineering faculty are finding that students who participate in study abroad programs are better problem solvers than those who do not. These students also have better communication skills and can better work in culturally diverse team environments and situations. [Shuman, 16] Downey et al. attribute this to the international experience engaging students so they can learn to work with people who define and solve problems differently. [Downey, 4]

PROJECT OPPORTUNITIES AT UTC

The University of Tennessee at Chattanooga (UTC), like many engineering programs, chooses to address the global and societal learning objectives within a course and a design project experience. Specific interdisciplinary design projects (involving some combination of chemical, civil, electrical, environmental, industrial, and mechanical engineering students) occur during the freshman, junior, and senior academic years. The freshman projects are embedded in the Introduction to Engineering Design (IED) course. The junior and senior projects are the main focus of the sequential Interdisciplinary Design I and II courses. Both design project opportunities include a variety of project types including industry supported, foundation supported, competition-based, and research-based projects.

Industry Supported

The industry supported projects are UTC's traditional approach to design project opportunity. These are offered to the upper level students in the Interdisciplinary Design course sequence. The projects support needs of facilities in the local Chattanooga area. These facilities may be local businesses or local facilities for a national or international company. For example, during the spring and fall of 2006 students supported projects at Komatsu American Corp. Chattanooga Manufacturing Operation, Advanced Transportation Technology Institute (ATTI) of Chattanooga, and Astec, Industries (Chattanooga based).

The opportunities presented to the students of these projects depend on the project application. For example, the ATTI project emphasizes improving the Wampfler Inductive Power Transfer (IPT®) system application presently used in Europe to quickly recharge batteries of electric powered buses for application in the United States. The Wampfler IPT® system is a contactless power transfer system based on electromagnetic technology. The system includes an in-ground primary coil and vehicle housed electromagnetic charge "pickups" and regulators. The challenge to the students is developing a device that (1) houses the pickups in the bus without impacting the passenger space, (2) lowers the pickups effectively to the appropriate distance from the primary coil for charging, and (3) positions the coil in the x and y planes to ensure maximum charging efficiency. To effectively address the goals, the student design teams have had to understand the Wampfler system, be introduced to electric vehicle and the IPT® technology, and be aware of the impact of the technology on the environment. An initial design of the

pickup mechanism is shown below (Figure 1.0). This design will be tested using a student developed test stand during the Spring 07 semester.

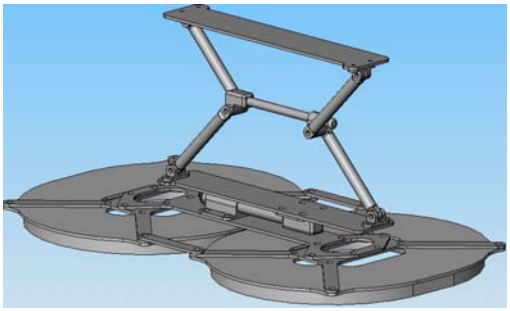

Figure 1.0 UTC Proposed IPT® Pickup Drop Mechanism

Foundation Supported

The IED and the Interdisciplinary Design students participate in projects supported by a grant from the Tennessee Department of Education. The focus of these projects is assistive technology for toddlers and young children. Signal Centers' Department of Assistive Technology is the project partner. Projects support children, families, and counselors in Chattanooga as well as the surrounding counties. During the 2005 – 2006 academic year 9 projects were completed and delivered to the children and centers.

A recent freshmen project involved creating a means to position a Springboard communication device for use by a child of very small stature and limited freedom of movement. Prior to project completion someone was needed to hold the Springboard device for the child while she used the device. The child and teachers needed a custom-built mount system that adapts to the child's wheelchair, her group activity wooden chair, and her floor activity.

Figure 2.0 UTC Student Designed SCDS

The Springboard Communication Device System (SCDS) the students designed and produced (see Figure 2.0) is made of Lexan, aluminum, and Delrin (a high quality, smooth plastic). The overall physical appearance, as shown in Figure 1, resembles a tray on a high chair, except a Delrin "strip and track" is included down the center of the tray to allow the block that holds the springboard to slide. At the end of the long Delrin platform is a shorter piece of Delrin that swings under the tray to allow storage for the springboard and space for writing, drawing, or coloring. Both Delrin pieces have locking pins to hold the block and Springboard in place.

Competition Based

During the 2005 – 2006 academic year the junior/senior interdisciplinary design sequence offered its first competition-based project – the SAE (Society of Automotive Engineers) Student Mini Baja competition. The goal of this competition is to simulate a real-world engineering design project complete with constraints and their associated challenges. Students plan, design, and build an off-road vehicle (see Figure 3.0) to survive the obstacles and punishment of rough terrain. The team competes against teams from other engineering programs across the US and abroad to determine which team wins the design "contract." The contract "win" is based on vehicle performance in categories such as endurance, performance, and safety as well as design team performance in categories such as

Figure 3.0 2006 UTC Mini Baja

design documentation and communication.

The 2006 – 2007 junior/senior interdisciplinary design sequence includes three competition projects – the SAE Mini Baja competition, the Northrup Grumman Corporation's Moon Buggy race, and the American Society of Civil Engineering's (ASCE) and the American Institute of Steel Construction, Inc's (AISC) student Steel Bridge competition. Each of these competitions simulates real-world constrained engineering design projects. Each emphasizes a specific discipline of engineering but benefits from the expertise of various other engineering disciplines. Each project has a project advisor and a technical liaison in the College as well as the course instructor as their project administrative staff. They must submit periodical progress reports to the administrative staff that include design selections and decision analysis, budget projections, and budget updates. In addition, project teams must plan and participate in marketing activities to acquire sponsored financial and/or material support for their projects. At the end of the fall semester all three projects submitted proposed designs (see Figure 4.0 for a CAD presentation of the UTC MoonBuggy design). Marketing activities are progressing based on the needs of these designs.

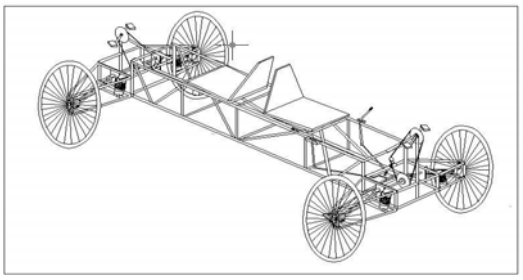

Figure 4.0 Proposed 2007 UTC MoonBuggy

Research Based

Another project opportunity students have at UTC includes those projects associated with faculty research. These are a new emphasis for the junior/senior interdisciplinary design sequence. Traditionally these projects were associated with only the research advisor and the research project and outcomes did not contribute to the interdisciplinary course. However, in the fall of 2006, two undergraduate research projects supported by two students participating in Departmental Honors projects were included in the project interdisciplinary activity as a trial test of their course contribution applicability. Both of the projects involved design components though the project teams consisted of one student and faculty researchers in and outside the student's engineering discipline instead of a team of engineering students from various disciplines.

One project involved simulating, using CFD-ACE+ multiphysics software and experimental microreactors, to understand how changes in packing arrangement and the number of packing particles affect micromixing and conversion efficiency in microbioreactor channels. The focus of this study was to optimize the placement and number of packing particles (see Figure 5.0) to more efficiently meet conversion goals.

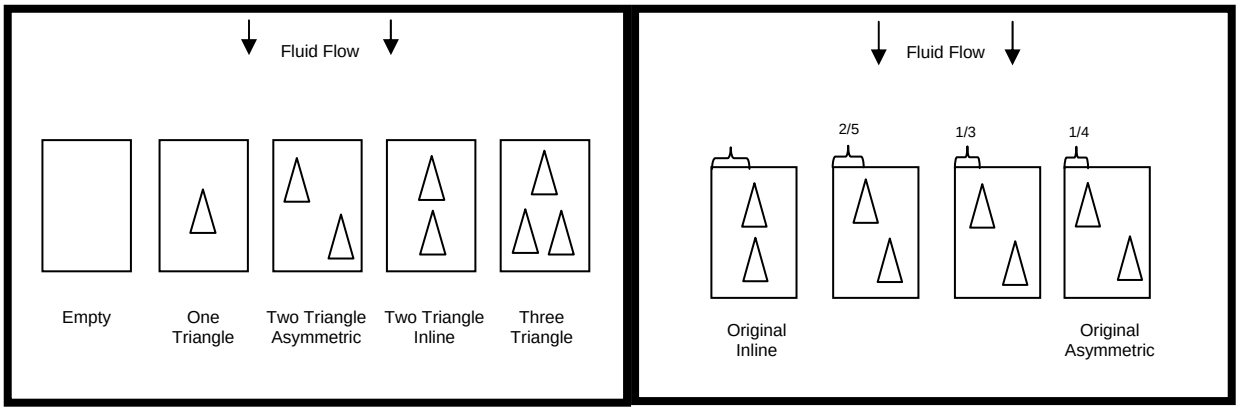

Figure 5.0 Microchannel Obstruction Configuration

The other project resulted in a new hip construct design and prototype for supporting a femoral neck fracture by identifying contributing design features based on the outcomes of performance tests on present hip construct designs (see figure 6.0). The student prototype was tested similarly and performance comparisons were made.

Figure 6.0 Hip Construct Prototype

UTC PROJECT CONNECTION TO SOCIETAL AND GLOBAL CONTEXT LEARNING

The above descriptions of projects illustrate the diversity of the projects in the UTC Interdisciplinary design courses. There are a variety of opportunities for the students so they can be involved in a project that is attractive to them. But as one looks at the projects, few of them have the direct global or societal connection identified in the present literature. One could say that the IPT project addresses both the global and social contexts. The technology addresses the sustainability of our energy resources and is presently used in a minimal capacity in European countries which traditionally have been more environmentally conscious than the United States. The hip constructs Departmental Honors project can be said to have a societal connection since it addresses technology and application that affects improving the lives of our aging population. The same is true for the microreactor project because, if the reasons for the need for the technology are considered, it is society that is identified as the benefactor since these reactors can improve production process including those that provide alternative fuels such as biodiesel. It is also true that the students supporting the assistive technology projects can experience the direct impact their designs have on a single child, a child's family, or an entire classroom of children with special abilities. They have the opportunity to quickly experience how engineering and engineering decisions can impact our society.

On average only half of the freshman students and one quarter of the junior/senior students each semester participate in the assistive technology projects. And the number of projects each semester which may have other indirect societal context can range from none to three or four. Since project team size is one (departmental honors projects) to seven or eight, this is a subset of those students participating in the interdisciplinary design experiences. And now that the student competition projects are managed within the junior/senior interdisciplinary design experience it appears that less students will participate in those projects that easily address engineering's societal context (the competition projects are popular with the students).

To counteract this deficit, the junior/senior interdisciplinary sequence requires all participating students to present and discuss the technical issues of their projects with their course peers. In this manner all students become acquainted with the technical, societal, and global issues of the projects. Students discuss such topics as the need for the specific technology and its role in our direct environment as well as the global environment. They also consider the future and what factors may change that could impact the need for the technology or change the technology application. This exercise is many times difficult to manage. Some projects, especially the competition projects UTC is presently participating in, do not naturally flow toward such discussion.

In addition, this discussion does not have the direct impact the study abroad or global teaming experiences have, especially with respect to the learning of global impacts,. The UTC students discuss possible global issues, which require them to consider how people and societies interact and work outside of Chattanooga and the United States, but they do not experience it. If, as the literature suggests, the most important outcome of the study abroad programs is learning how to work and communicate with people who make decisions and solve problems differently, the UTC program is not meeting this outcome. The closest the students come to this experience is working with students and industry partners who come from different backgrounds, be them from the United States

or abroad (UTC engineering has a very small population of foreign born students). Also, few of our engineering students take advantage of study abroad experiences. Those that do travel with the Honors Program participate in experiences not connected to an engineering application.

CONCLUSION - FUTURE DIRECTION

When the original interdisciplinary experience was designed for the UTC engineering students in the 1970s, the goal was to provide the students a controlled real-world experience so they could be prepared for a variety of expectations when they enter the work force. This goal is the same today; however, the expectations of the work force that have changed. The "real-world" application is more than the immediate Chattanooga region. The people the engineering graduates will interact with to solve problems come from all over the world and the problems the graduates will confront many times have direct impact on our local as well global societies. The learning moments in UTC's interdisciplinary design courses address these changes. However, if the present literature is correct, this is not enough for the students to fully understand the impact of engineering solutions in a global and societal context. The students need to have some form of interaction with society as well as the global community to internally interpret the impact similar to what active learning does for academic concepts in the classroom.

The program to improve assistive technology for young children is one step to getting that direct societal experience. The students who participate in these projects express that they are motivated by knowing that what they are designing is improving the life of a child or the lives of a number of children. They realize that engineers can have a role in helping make a portion of our population, which not too many years ago had to live in assisted living communities, have independent and contributing lives. In addition, the local community, through public relations opportunities and presentations, has become more aware of the contribution of engineers to the local society. It has a resulted in local programs requesting assistance from the engineering program for projects that directly affect the community. This has had further impact on the students as to the role engineering can play with respect to societal issues. Thus, it is UTC's goal to enhance this program to support more service-based projects from the local community. This will require enhancing the grant support as well as shop capabilities.

Going outside of Chattanooga and bringing the global and society issues to the UTC students has proven more difficult. As is true of many institutions, the UTC engineering program is small and many of its students work at least part time to support themselves and sometimes families. It is not realistic for the students to take a leave from their work and families to participate in a semester length study abroad experience. So the UTC program is struggling to determine how to bring these experiences to the students. A small step in this direction occurred in the fall of 2007 when three of UTC's students participated in a national conference on the west coast. These students presented their undergraduate research during the student poster sessions and met many students and faculty from not only across the nation, but from the world. When asked what they learned from this experience, all three mentioned that they were surprised how many foreign students and professors were at the conference and that they had difficulty communicating their research with these individuals. They inferred that it was not the language difference that made it difficult but it was the different interpretation of the research problem and the different view of the analysis that made it difficult. They had experienced what the literature tells us is the most important learning opportunity from global experiences – that people from different cultures may solve problems differently. Due to this affect, it is now UTC engineering's goal to get more of our students out of Chattanooga and into short term national and international experiences that get them communicating with people educated in different cultures. These experiences can be conferences or short courses.

The student competitions are also a means of getting students communicating with others but what role do the competition projects play in providing engineering students with societal and global context learning opportunities? UTC engineering is still struggling with this relationship. The competition projects are new to UTC's project offerings and thus the faculty has little experience with what students experience as participants. But the faculty has become aware that some competition projects can require students to become locally and globally aware of technology and its societal role. For example, the alternative fuel vehicle competition (Chem – E – Car) sponsored by the American Institute of Chemical Engineers (AIChE) can necessitate that students learn of global alternative fuel applications and research as well as the present and future local and global impacts. It may be that, in the future, UTC considers more heavily the societal and global learning opportunities when selecting student competitions.

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