The Collegiate Wind Competition – Undergraduate Education through Student Competition

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Abstract. The Department of Energy has offered the Collegiate Wind Competition (CWC) since 2014. Penn State and Northern Arizona University are two of four Universities that have fielded teams in each of the competitions since this inaugural year. This paper aims to highlight the ways in which these two programs have integrated the CWC into their curriculum, evolving with time, and also how this competition has tried to meet the needs of providing a diverse, educated workforce prepared for a wide variety of tasks in the wind industry.

1. Introduction

Wind Energy Education is not typically part of the core curriculum within traditional engineering disciplines at the undergraduate level and there are few degree or certificate programs geared specifically towards wind energy at the undergraduate level in the United States. As such, most programs desiring to bring Wind Energy Education into their curriculum, might do so via their respected capstone sequences and/or other design courses, adding wind-specific elective courses or independent studies, or even starting extracurricular academic clubs specific to the topic. To help trigger the proliferation of Wind Energy Education at the undergraduate level, the Department of Energy (DOE) started the Collegiate Wind Competition (CWC) which “challenges interdisciplinary teams of undergraduate students from a variety of programs to offer a unique solution to a complex wind energy project... [and] providing each student with real-world experience as they prepare to enter the wind industry workforce” [1]. The 2020 competition has two main objectives:

- design, build and test a wind-driven power system for a desired application or test conditions and present the technical design to a panel of judges.
- detailed site design and financial analysis for a wind project to be documented in a report as well as presented to judges.

The competition has evolved over the years, and at times has also required a business plan as well as on site challenges. The overall educational objective for teams working on this project will then be to educate students specifically in the two areas stated above and to support the team with an array of university and industry resources. Outlined in Figure 1, The Wind Power Plant Project Development Plan will require: a detailed site design and a financial analysis with deliverables that include a formal report and a presentation at the competition. The Functional Wind Turbine will need to be designed
and built with deliverables that include a formal report and on-site testing at the competition. Both will adhere to the 2020 Collegiate Wind Competition Rules and Requirements (CWC20 R&R) document.

![Figure 1: Project Objectives](image1)

The overall tasks to be completed per the Statement of Work for the 2020 Collegiate Wind Competition [2] can be seen in Figure 2. Faculty Planning and Team Development (Task 1) occurs prior to the start of the academic year and continues through the start of the Fall 2019 semester. In late August 2019, the Principal Investigators and one student representative from each team will attend the virtual Kick-Off meeting (Task 2) per the statement of work. At the end of AY2019-2020, the team will submit the required reports ahead of time and then attend the competition to test the turbine, present the turbine design and the plan for the power plant, perform the on-site siting challenge, and visit with the KidWind students (Task 3). After the competition, the team will collect data for the Impact Evaluation report per the requirement to end the contract (Task 4).

![Figure 2: Statement of Work Tasks](image2)
Figure 3 shows the detailed deliverables required of the team before the end of the contract along with the due dates.

![Deliverables Diagram]

Figure 3: Project Deliverables

The competition teams are selected via a competitive proposal process that provides funds to support the team with team fundraising also expected. For the 2020 Collegiate Wind Competition, twelve universities were ultimately selected:

- California State University, Chico
- California State University Maritime Academy
- James Madison University
- University of Maryland
- University of New Haven
- Northern Arizona University
- The Pennsylvanian State University
- Texas Tech University
- Tuskegee University
- Virginia Polytechnic Institute and State University
- Washington State University-Everett with Everett Community College
- University of Wisconsin-Madison

Although this competition, held since 2014, has been an excellent catalyst for curriculum development and integration within the undergraduate programs that attend the competition, challenges still remain for those students seeking gainful employment within the Wind Energy Sector and diversity challenges within the respective engineering disciplines remains relatively unchanged from national averages – though there are some signs of improvements.
2. Methods
Pennsylvania State University (PSU) and Northern Arizona University (NAU), uniquely different universities, have found success in their respective approaches to integrating Wind Energy Education through the CWC into their curriculum. An overview of these approaches is provided in the following sections.

2.1. Pennsylvania State University
The PSU team has employed multiple approaches to managing the Collegiate Wind Competition activity, including special topics courses, independent study and through coordination as a club activity. In the inaugural competition year, much of the activity for the Penn State team was coordinated through a special topics/projects based course as well as projects in existing courses. Because the program began as an every-other-year competition, in late 2015 the PSU team members created the PSU Wind Energy Club to help maintain a more consistent level of activity. Having club status also allowed the team to access recruiting mechanisms across the University and other student activity rights which weren’t available to them previously such as travel support and classroom reservations. Once the club was formed, the bulk of the team coordination has been run through the club as a volunteer activity, with independent study or special topic/project credit offered to those who desire a more significant commitment. About half of the active CWC students would generally sign up for 1-credit in the fall semester, as they ramp up activity, and 2-credits in the spring semester and could use the combined 3-credits as an elective in their curriculum. EGEE 438 – Wind and Hydropower Energy Conversion is also offered every Spring and is required for students in the energy engineering major. Ideally, more of the Wind Energy Club students would take EGEE 438 as a prerequisite or while working on CWC activities, but this hasn’t generally been a common cross-over for non-energy engineers. This course covers an overview of the wind industry, wind resource assessment, basic aerodynamics and annual energy assessment as well as project development basics.

Thus, for the 2020 Competition, a fall 3-credit wind special topics course, AERSP 497 – Collegiate Wind Competition, will be offered to bring more background content to the team members who desire this knowledge. The course will meet two times per week and is being designed to be as inclusive as possible in terms of background. A point-based system has been developed to allow students to choose how they would like to structure their learning outcomes to tailor to their interests and roles in the competition team, while some assignments will also be required. In particular, the course will introduce Project Drawdown and the importance of wind energy as a climate change solution and also expose the students to potential careers in wind energy. Prof.’s Stewart, Auhl & Schmitz will manage this course and also bring in guest lecturers from industry.

The PSU Wind Energy Club will still operate in parallel so as to not turn away students not taking the 497 course who want to be involved in the competition activities, thus we will still hold weekly club meetings and sub-team meetings in which other members may get involved with the competition as well. Presentations that are related to competition progress will be limited to the club meetings so that all team members will be included in these activities. Recordings of 497 lectures will also be made available for students who either have a conflict with the class meeting time or club members seeking the content but not the credit commitment.

The broad tasks to be tackled by the project team over the course of the competition are described in the Project Schedule shown in Table 1 with Competition deliverables denoted by the red stars.
2.2. Northern Arizona University

While PSU has found success outside of the classroom in a club environment as well as through independent studies, NAU has found success through utilizing existing capstone mechanisms within their curriculum, a Wind Energy course in the Mechanical Engineering Department, as well as through independent studies and outside advising. Though this has brought initial success through the first few years of the competition, NAU has since made the following changes:

- Added an Electrical Engineering Wind Power course
- Tailored independent studies to meet the competition challenges
- Added “feeder” projects in the junior level design course
- And enthusiastic students have formed an Energy Club at NAU (founded in 2018)

In order to support the objectives of the competition for the 2020 competition, Team NAU will utilize existing mechanisms within their curriculum such as senior capstone design courses, the junior design course, existing wind energy courses, an independent study, visiting industry experts, and the newly founded NAU Energy Club. Figure 4 details the curriculum integration plan with three main paths: Mechanical Test Turbine Design, Electrical Test Turbine Design, and Wind Power Plant Project Development Plan. From past experiences at NAU, success in multidisciplinary design projects was found in maintaining disciplinary curriculum lines for targeted teaching and assessment of course and project learning outcomes. As such, the test turbine design will be split up into the disciplinary capstone sequences. The Mechanical Test Turbine Design team will be seated in the ME capstone I & II design sequence and be supported in the fall with the ME Wind Energy Design Course. The Electrical Test Turbine Design team will be seated in the EE capstone I & II design sequence and be
supported in the spring with the EE Wind Energy Design Course. The Principal Investigators at NAU recognize the challenges associated with splitting up the test turbine team into separate disciplinary design sequences. Therefore, the integration of the two turbine design teams will be maintained in weekly advisor meetings through the fall and spring semesters as well as through the Energy Club and in accordance with the CWC20 R&R document. NAU has successfully used this model for integrating the CWC project into curriculum and managing the multidisciplinary team in past years.

For the Project Deliverables (Figure 3), the PI and one student representative will attend a virtual Kick-Off meeting (Deliverable #1). PIs and the leads team will write a 1-page team and project story and the whole team and PIs will take at least three team photos (Deliverable #2). The team Portfolio components that include the reports, drawing package, and specification sheet will be the responsibility of the whole team with the team’s leads being the primary authors and the PIs giving feedback on drafts. The team photo, videos, marketing material, and release forms will be the responsibility of the team leads and the PIs to organize (Deliverable #3). A select group of the team (depending on interest and need) as well as the PIs will be travelling to the competition where students from Team NAU will give two presentations, test their turbine, and compete in the on-site siting
challenge (Deliverable #4). After the competition, the PIs will collect data from the team for the final activities and impact report (Deliverable #5).

3. Job Placement

The National Renewable Energy Laboratory and the Center for the New Energy Economy recently surveyed wind companies and wind energy education institutions in order to analyze the workforce needs, available training and also the “workforce gap”[3]. What they found was that the majority of respondents from wind companies had difficulty hiring qualified candidates while representatives from education institutions reported graduates not having jobs once they graduated or not entering the wind industry. Figure 5 shows the reasons why graduates did not enter the wind industry, according to education institution representatives [3].

![Figure 5: Reasons why graduates did not enter wind industry [3]](image)

The CWC program is intended to help reduce this workforce gap and to ultimately grow the wind workforce. But similar results have been seen with alumni of the CWC program.

3.1. Job Placement at Northern Arizona University

Job placement for NAU graduates specifically into the Wind Sector has been challenging. And instead of seeing a large portion of our CWC alumni finding employment within the Wind Sector, NAU graduates (with a few exceptions) are spread out into other industries such as aerospace, biomedical, automotive, military, or other energy related positions within electric utility and solar energy companies.

3.2. Job Placement at Penn State University

Despite having great success with the competition, winning four out of six competitions, few PSU CWC alumni have been successful in landing jobs with wind or renewable energy companies. Part of this issue for PSU is that students are highly recruited by other industries as NAU has described as well. Though alumni from both programs are entering into a diverse range of fields, it seems they have greater success in obtaining these positions with the added experience and knowledge of the CWC.

3.3. Some Final Thoughts on Job Placement

Although similar anecdotal results to the Wind Energy Workforce report stated above can be seen from both NAU and PSU, a thorough collection of data specifically from CWC alumni would be able to assess the effectiveness of such programs in decreasing the workforce gap in wind energy and ultimately provide insight into similar efforts. Schools participating in the competition would like to
see more interest from the Wind Industry in hiring CWC students and alumni. To help with increasing interest, a survey could be generated to ask questions such as:

- Are your hiring managers aware of the Collegiate Wind Competition?
- Are you aware of the skills that students who attend the CWC gain?
- What does the CWC do to reduce what you perceive as the workforce gap? Where could it make improvements?
- Would you be willing to partner with one or more wind energy education programs to help improve training in order to reduce the workforce gap?
- Would you be willing to offer internships and/or scholarships for CWC students to help promote your needs to the students while adding valuable training to future members of the wind energy workforce?

4. Diversity

Per the Wind Energy Workforce report [3], electrical and mechanical engineers within the wind energy workforce are made up of just 10% women, 16% racial and ethnic minorities, and 6% veterans. Meanwhile, McKinsey and Company’s report tackling the business case for diversity [4] found that “companies in the top-quartile for gender diversity on executive teams were 21% more likely to outperform on profitability and 27% more likely to have superior value creation.” Additionally, “companies in the top-quartile for ethnic/cultural diversity on executive teams were 33% more likely to have industry-leading profitability.” Aiming to achieve a more diverse and inclusive wind workforce is an additional objective outcome for the CWC program and NAU and PSU are continually aiming to strive for achieving a diverse student make-up on our teams.

4.1. Diversity at Northern Arizona University

Northern Arizona University is unique with a large percentage of first-generation students and a diverse student population as a whole from all corners of Arizona, parts of California and other western states, as well as a growing international student population. Past CWC teams from NAU have been a great sample of our programs and future successful teams will represent the changing demographics though time. Evidence of this potential for further inclusivity can already be seen in the newly formed Energy Club where diversity is exceeding the trends in our engineering academic units. Diversity in student background on this project at NAU through the years has come in waves. One year- team NAU will be representative of the general population and then the next year will be closer to national averages in engineering and science [5]. These waves anecdotally seem to coincide with the competition’s two-year cycle – where slightly more diverse teams are seen on off year teams. To help this, the Energy Club, which has seen more diverse numbers than the general engineering student population, should serve as a mechanism removed from the typical recruitment strategies and capstone selection process. Higher diversity in majors is seen on on-year teams to meet the challenges of the competition.

Past CWC teams at NAU (from AY2013-2014 to present) have also demonstrated success across disciplines – where collaboration between colleges and academic units was paramount to successfully competing in this competition. In the past, the Mechanical and Electrical departments within the College of Engineering, Forestry, and Natural Sciences (CEFNS) have collaborated well with the Franke College of Business and their faculty. For this next competition, there will not be any need for collaboration with the Franke College of Business since there is no business plan component per the statement of work. Also for this next competition, it is worth noting that the Engineering and Professional Programs (EPP) – which includes the School of Informatics, Computing, and Cyber Systems (SICCS) – have since split from CEFNS to form the College of Engineering, Informatics, and Applied Sciences (CEIAS) with a dean’s office dedicated solely to the EPP academic units that it represents. As such, collaboration within the newly formed CEIAS should be even easier logistically – where collaboration between the Electrical and Mechanical Engineering departments, specifically, will...
be key to the overall success of the project. Though these are the two primary academic units working on this project, other students from other units (Business, Economics, Environmental Sciences, and Political Sciences) will be invited to join the team and pending the final version of the R&R document they may even be needed for specific deliverables to be successful.

4.2. Diversity at Penn State University
The PSU team has had as many as 50 active students across 17 different majors in a given competition year. Recruitment is possible through PSU involvement fairs, but we often find word of mouth is the best recruitment tool. This organic growth can work out well, but keeping students engaged rests heavily in the hands of the team leaders. We are still working to improve in this area and also find a better gender equity balance. The course will be offered for CWC students for Fall 2019, AERSP 497, has been developed with the intention to not only allow for a broad variety of majors and backgrounds to get involved in the team, but it is also designed to try to help with retention of students early in the competition. This has been a challenge for our team in getting ramped up and having an organized course should help keep the teams more organized overall, which will help make sure there is a place for everyone who is interested in participating to maintain their involvement and interest in the team. Thus, this allows for a more inclusive environment.

5. Conclusions
The Collegiate Wind Competition provides a mechanism for Universities to integrate a compelling, hands on and engaging wind energy educational activity into academic programs. The ways in which different institutions approach the challenge and provides meaningful ways for students to get involved in the competition can vary widely, but there are also many similarities. Two perspectives have been presented in this paper showing how both began their journey in this event and how they evolved with time to try to meet the ever increasing challenges of the competition, how each program has tackled challenges of the workforce gap in the wind industry and how they are aiming to provide an inclusive environment for a diverse future workforce.

Northern Arizona University and Penn State University have been competing in the Collegiate Wind Competition since its inaugural year, 2014. Both programs have tried integrating the competition into instructional courses, independent study, as well as a volunteer club activity. Both programs are using a combination of these approaches for the 2020 competition.

Both programs have identified a challenge with placing students in wind careers upon graduation despite the growing need for wind energy professionals [3]. This generally seems to be due to strong recruitment by other industries at the institutions. The skills the students acquire participating in the competition are highly desirable across many fields. General awareness of the Collegiate Wind Competition within the wind industry could be improved through surveys and communication with hiring managers.

The Collegiate Wind Competition is cognizant of the importance and value of a diverse wind workforce and this workforce starts at our educational institutions and also involves setting the example with an inclusive environment for our students. Both institutions have worked to provide inclusive learning environments and are also striving for diverse student involvement on their teams. The nature of the Collegiate Wind Competition has also encouraged a broad range of majors to participate in the competition, bringing many students across campus together who may not normally collaborate on projects.

Continued participation in the Competition has allowed for an ongoing, enriching academic as well as co-curricular experience for students at the two institutions. Other similar types of competition programs, Eco-Car, Solar Decathlon, Design/Build/Fly, for example, see similar benefits to their students.

References
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