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Value Perceptions of Industry Interactions in a National Airport Design Competition

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Value Perceptions of Industry Interactions in a National Airport Design Competition

Abstract

Interactions with subject matter experts during student design activities is an idea embraced by many faculty as a crucial component of a design course. However, the process of involving experts is challenging and takes a significant amount time in a semester that is already packed with other course requirements and activities. Furthermore, meaningful interactions between students and experts requires that students be trained on interaction etiquette, and on responsible conduct of research. With other priorities demanding student and faculty time, realizing interaction between industry experts and students in design courses may not achievable. Research to understand the value of expert interactions may inform educators as to the pedagogical value and provide support for including these activities in design courses.

Graduate and undergraduate engineering and technology students from across the United States compete annually in the Airport Cooperative Research Program (ACRP) airport design national competition. The competition rubric consists of a total of 130 points allocated to different sections with 12 points allocated for interactions with experts. By analyzing the winning design packages, the researchers seek to understand the contributions of expert interactions especially those that informed design choices, as reported by the student teams. The design submittals that were awarded first place, second place and third place from 2015 to 2020 were collected and analyzed using quantitative and qualitative research methods. A study of the reported interactions with experts in a design course may enhance understanding of the value that these interactions have on the educational experiences of students in design courses. Understanding the value of the interactions may provide educators incentives to include expert interactions in design courses.

Introduction

Many faculty teaching design courses may acknowledge that a crucial component is external interactions between the students and the industry experts. However, the process of involving experts is challenging and takes a significant amount of time in a semester that is already packed with other course requirements and activities. With other priorities demanding student and faculty time, realizing interaction between industry experts and students in design courses may or may not be achievable. Research to understand the value of expert interactions may inform educators as to the pedagogical value and provide support for including these activities in design courses.

In this paper, the Airport Cooperative Research Program (ACRP) Design Competition was selected for three reasons: 1) interaction with experts is part of the competition requirements, 2) winning design proposal packages are available on a website for the ACRP Design Competition [1], and 3) the authors have participated in the competition either as part of student teams or as faculty advisor. The competition website includes competition guidelines, evaluation rubric, submission files to be part of the design proposal, winning packages, resources to help student teams, and deadlines [1].

Airport Cooperative Research Program (ACRP) conducts an annual airport design competition for university-level students in which U.S. student teams propose innovative designs to solve challenges facing U.S. airports [1]. Undergraduate and/or graduate students are eligible to participate in the competition either as part of a course or as an independent project with faculty sponsor(s). The students, either individually or in a team, prepare a 40-page design package proposal addressing innovative approaches related to airport challenges. The design competition requires student teams to interact with airport operators and industry experts to get input on their design ideas and solution [2]. This paper explores the number and value of these interactions by evaluating the winning design proposals.

Statistics are used to analyze trends in the winning design proposals which may reflect the importance of number of the experts contacted by student teams and their demographics. The winning design proposals contain written sections that discuss the team's reported benefits of their interactions with industry experts. Thematic analysis is used to identify themes for design proposals from first, second, and third place teams. The paper presents a study of these reported expert interactions. The results of this paper may inform future teams to focus their industry interaction efforts toward creating better design proposals. In addition, course instructors may find the results of their study useful in incorporating expert interactions in other types of design courses.

Background

This section presents a discussion of literature regarding industry involvement in design projects and expert interactions required in the ACRP design competition. One of the goals of engineering and technology programs is to prepare graduates for the industry by imparting theoretical knowledge and practical problem-solving skills. In collaborations with industry, universities can design hands on projects where students participate in solving 'real' world challenges, a task that can equip students with technical and soft skills that are necessary in the industry. Experiential learning experiences such as capstone projects is one way for students to gain hands on industry experience as they prepare to enter the industry [3]. Other ways students can gain hands on experience is through internships and cooperative programs. Through collaborative projects between schools and industry, students learn to:

- apply theoretical knowledge to solve practical problems,
- communicate effectively with their industry consultants and fellow student team members,
- understand financial impacts of problem solutions,
- work in teams,
- to understand industry demands such as setting and meeting deadlines, and other constraints,
- among other technical skills and interpersonal skills [4].

Designing a project that involves industry experts has its challenges, and such a project must meet certain criteria [5]. Five factors to consider are:

(i) project must be relevant to the students and their program majors,
(ii) students should be expected to invest a significant amount of time on the project,
(iii) students should be able to complete the project within a certain time frame,
(iv) project should be manageable and within the abilities of students, and
(v) project should be managed so that all students in class participate fairly [5].

Several studies have reported that inclusion of industry in students' projects present a win-win benefits for all parties involved [3], [4], [5]. From experiential learning projects, students get hands-on experience working on a project and can exercise room for error with minimal risk to their careers - a chance that might not be afforded in a work environment [4]. Both industry and schools could benefit from partnerships that allow students to exercise their creativity because students may raise questions that might otherwise be missed by industry representatives and faculty. Furthermore, the industry might benefit as there may be minimal capital investments when students carry out a project [3], given that is properly scoped and managed.

Another way for students to interact with experts is to participate in national design competitions. In the United States (US), the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM) manages an applied research program that develops near-term, practical solutions to airport challenges [6]. One of the components of the TRB is the Airport Cooperative Research Program (ACRP) which is authorized by the US Congress and sponsored by the Federal Aviation Administration (FAA) [6]. The ACRP University Design Competition for Addressing Airport Needs involves undergraduate and graduate students working with faculty advisors to propose innovative solutions to address airport related issues focused on four broad airport related areas: Airport Operation and Maintenance, Runway Safety/Runway Incursions/ Runway Excursions, Airport Environmental Interactions, and Airport Management and Planning [1]. Student teams are free to either address specific challenge areas as defined in the Technical Design Challenges section of the ACRP design competition guidelines, or propose design solutions based on other topics that fit the four broad challenge areas [1].

The evaluation criteria for the design competition are available on the ACRP website [7]. The criteria are used by the competition judges to evaluate design proposals, and could assist student teams to evaluate and improve their proposals before final submission. Each of the design proposals submitted are evaluated, and evaluators may choose to provide a score in half-point increments [7]. Table 1 presents sections of the point distribution for the evaluation criteria. Design proposals have been submitted by individual students, project teams, and capstone project design teams.

Table 1. *Summary of Point Distribution for Evaluation Criteria [7]*

Evaluation Criteria Categories	**Possible Points**
Introductory Material	5 points
Problem Statement and Background	10 points
Literature Review	11 points
Problem solving approach	34 points
Safety Risk Analysis	8 points
Evidence of effective interaction with airport operators and industry experts in the design process	12 points
• Is there evidence of effective interaction with an airport operator and impact on the design process/result?	• 6 points
• Is there evidence of effective interaction with one or more industry experts with a resulting impact on the design process?	• 6 points
Practicality and Feasibility of the Proposed Design	20 points
Innovation	14 points
Overall quality of design	16 points
Total	**130 points**

Part of the ACRP design competition guidelines require student teams to show "evidence of effective interaction with airport operators and industry experts in the design process" [2], and is highlighted in Table 1. The interactions with airport operators and industry experts carries 12 out of the 130 points. It is important to note that competition guidelines require that students interact with both airport operators and industry experts to earn the full 12 points [7]. Evidence of effective interaction should be clear in the submitted design proposal [1]. The student teams may interact with the experts remotely or in-person. At least one professor invites experts to participate in class discussions via telecom or in person. The nature of the interaction is at the discretion of the student team and the concerned expert.

The ACRP competition website provides a list of 'Expert Advisors' and their contact information to help student teams identify experts in the four design challenge areas [8]. Student teams participating in the design competition may contact these experts; moreover, students may correspond with other subject matter experts outside of the ACRP experts list as needed. Student teams may also collaborate with non-university partners to work through the design challenge.

Research Questions

The research team identified three research questions to better understand the potential impacts and the perceived benefits of interactions with industry experts on the winning designs. This research is limited to the ACRP University Design Competition for design proposals between 2015 to 2020 that were awarded first, second, or third place. The research team does not have access to the other proposals submitted. In this study of the winning design package submittals that were awarded first, second, or third place, the number of experts interacted with are compared across place award and challenge areas. In addition, the team sought to better understand the perceived benefits of interactions with industry experts as reported in two sections:

- the evidence of interactions with airport operators' section, and
- Appendix E. Question 4: "Was participation by industry in the project appropriate, meaningful and useful? Why or why not?" [9].

The three research questions were:

- Research Question 1. Is there a statistically significant difference in the number of experts interacted with across first, second, and third places?
- Research Question 2. Is there a statistically significant difference in the number of experts interacted with across the four design challenge areas?
- Research Question 3. What are the reported benefits of the interactions with industry experts in the design proposals?

Methodology

This section discusses the data sources and data collection for this study. The data sources are the winning design competition packages published on the competition website. For the years 2015-2020, the annual ACRP design competition invited proposals in four categories:

A. Airport Environmental Interactions,
B. Runway Safety/ Runway Incursion/Runway Excursions,
C. Airport Operations and Maintenance, and
D. Airport Management and Planning.

The winning student design submittals are announced around mid-summer every year and published on the ACRP website accessible to the public. Each design proposal has a 40-page limit excluding required appendices to address innovative solutions related to airport issues. Students may show "evidence of effective interaction with airport operators and industry experts in the design process" [7] as a specific section in the main body of the design proposal. Teams typically include a section of the report for industry and expert interaction; however, some teams do not designate a section for this information. In addition, students are required to submit Appendix E which asks the student teams to report the value of the expert interactions. In Appendix E, Question 4 asks, "Was participation by industry in the project appropriate, meaningful and useful? Why or why not?" [9].

The research team retrieved information directly from the 'Interaction with Airport Operators and Industry Experts' section of the design packages. Additional data was collected from Appendix E Question 4. In some cases, researchers read through several sections of the proposals to identify any interaction of student teams with experts, if the interaction was not mentioned explicitly in the report. In three reports, data about experts was collected from Appendix A which includes the contact information of the team members and advisors; however, sometimes it included the experts contacted by the team [2].

Researchers extracted first, second, and third place winning design proposals for the years from 2015 through 2020 by accessing the ACRP airport design website [1]. A total of 58 design proposals were collected. Figure 1 (a)-(c) show the breakdown of number of design packages according to place awards, years, and design challenges.

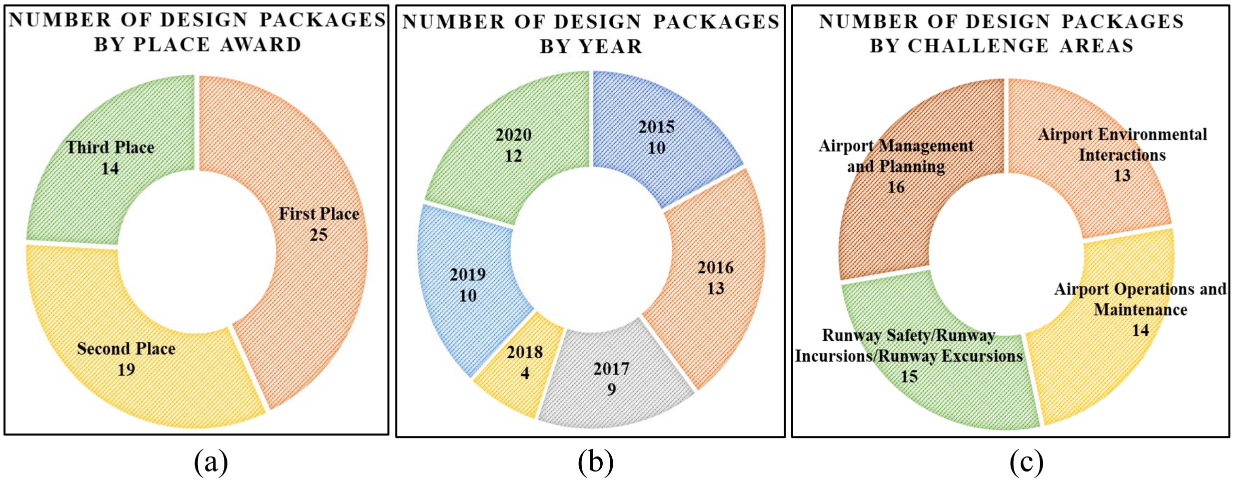


Figure 1 (a)-(c). A total of 58 winning design proposal packages were selected for analysis.

Out of the 58 packages, one design proposal was not available on the ACRP website; therefore, no information could be collected for that proposal [10]. The data set includes a total of 57 design proposals that were used for statistical and thematic analysis. In any year, ACRP Design Competition may not award any or all places for each challenge area.

Researchers extracted information from the first, second, and third place design proposals available on the website. The information included title of the proposal, design challenge area, place award, university of the teams, number of experts the teams interacted with, professional affiliations of the experts, and evidence of expert interactions as explained in the design proposals. This information was retrieved from the winning design proposals available on the ACRP competition website.

Data Analysis Procedure

Each design proposal was reviewed by each of the three researchers in the team. The 57 designs identified were analyzed using qualitative and quantitative analysis methods. The research team summarized the numbers of winning proposals by universities and number of awards. An expert was considered as a valid count only if the expert contact was explicitly mentioned in the design proposal, or the exact number of survey respondents was reported in the proposal. The data analysis procedure for each research question is shown in Figure 2.

To address Research Question 1 and Research Question 2, the research team followed these steps:

Step 1: The number of experts were counted and tabulated in each of the design proposals across the three place awards and across the four challenge areas.
Step 2: The total number of reports and total number of experts interacted with were counted and compared across the three place awards and the four areas.
Step 3: The median number of experts per proposal was calculated in each of the three place awards and four challenge areas. These calculated medians represented the *sample* median number of experts as found from the 57 design proposals, from 2015 to 2020.
Step 4: The Kruskal-Wallis Test was used to test if the *population* median number of experts differed across the three place awards and four challenge areas. The median number of experts was charted from 2015 to 2020 for place awards and challenge areas.

To address Research Question 3, the research team followed these steps:

Step 1. Each of the three members of the research team reviewed two sections for each of the 57 winning design submittals retrieved from the ACRP website. The two sections reviewed are: (1) Evidence of effective interaction with airport operators and industry experts in the design process, and (2) Appendix E – Question 4: Was participation by industry in the project appropriate, meaningful, and useful? Why and Why not?
Step 2. From the two sections, the team jotted down notes with keywords and phrases used to describe industry interaction in the design proposals. First place proposals, second place proposals and third place proposals were reviewed separately.
Step 3. The team used affinity diagrams to group similar keywords and phrases in each of the three place awards of design proposals (i.e. An affinity diagram was developed for first place keywords and phrases, second place keywords and phrases and for third place keywords and phrases).
Step 4. The team then identified an overarching theme for each group identified for each of the three placements.

Researcher Bias

The research team consists of one full-time professor who has advised student teams for the ACRP airport design competition, and two graduate students who have each participated in past ACRP airport design competitions. The three researchers have conducted research on airports and continue to research in this area. Researcher bias is reduced by the use of multiple researchers examining the student design submittals, and then comparing the results. Researchers discussed the results to arrive at a consensus.

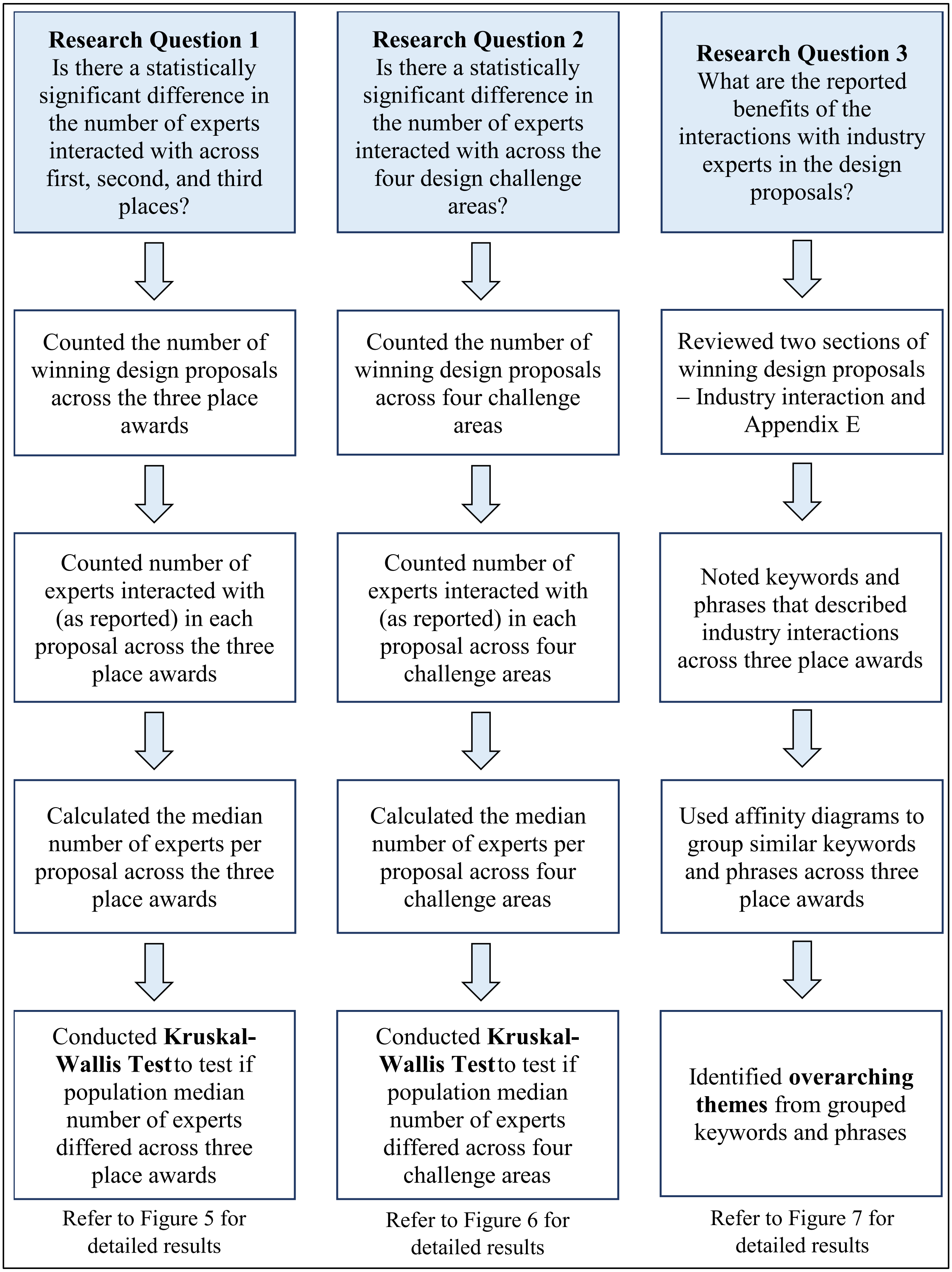


Figure 2. Data analysis procedure flow diagram

Results

This section presents an analysis of the data collected from 57 winning ACRP design submittal in the first place, second place and third place for the years 2015 to 2020. In addition, the results of the research questions are presented.

Counts of first, second, and third place winning design proposals from 2015 to 2020 by university are shown in Table 2. The winning proposals are tabulated by universities, total number of place award proposals, number of first, second, and third place awards, and number of awards in the four challenge areas. From 2015 to 2020, there were 58 winning design proposals from 24 universities and 16 States. The total number of place awards won by each university.is the sum of their first, second, third place awards. Of the 58 winning proposals from 2015 to 2020, Purdue University has won 17 (29%) place awards, and Binghamton University – The State University of New York has won 6 (10%) place awards. The ACRP Design Competition does not publish the total number of proposals submitted per year. No information is available on the website about the proposals that do not win a place award. In any year, ACRP may not give awards for each challenge area and each place. For instance, in 2018, no submittals qualified for a first place, second place or third place under the 'Airport Environmental Interactions' category [11]. ACRP does not have to award a winner if no submittals qualify.

By reading specific sections of the packages, the research team counted the number of experts mentioned in the reports. Table 3 shows the number of experts mentioned in the design proposals, for each of the 58 packages submitted by the student teams from the 24 universities in the data. One design proposal was not available on the ACRP website and is shown as 'NRF – No Report Found' in Table 3. The researchers selected the median number of experts as the measure of central tendency because of skewed data and presence of extreme values.

Table 2. *Winning design proposals by universities, place awards, and design challenge areas from 2015 to 2020*

University	Total Number of Award Winning Proposals	Place Awards			Design Challenge Areas			
		First Place	Second Place	Third Place	Airport Environmental Interactions	Airport Operations and Maintenance	Runway Safety/Runway Incursions/ Runway Excursions	Airport Management and Planning Challenge
Binghamton University – State University of New York	6	1	3	2	1	2	1	2
Embry-Riddle Aeronautical University	1			1			1	
Florida Institute of Technology	1	1					1	
Georgia Institute of Technology	1			1		1		
Kansas State University Polytechnic Campus	1		1			1		
Michigan Technological University	2	1	1		1		1	
Old Dominion University	1		1					1
Penn State University	3			3		2	1	
Purdue University	17	9	5	3	3	3	4	7
Roger Williams University	2	2			1	1		
Rutgers, the State University of New Jersey	2	1	1		1			1
San Jose State University	1			1	1			
Stevens Institute of Technology	2	1		1		2		
The University of Texas at San Antonio	1		1		1			
Tufts University	2	1	1			1	1	
University of California, Berkeley	3	1	2		2	1		
University of Colorado, Boulder	2	2			2			
University of Massachusetts	1	1					1	
University of Missouri – Columbia	2			2			1	1
University of Nebraska	1	1					1	
University of Rhode Island	3	3					1	2
University of South Florida	1		1					1
University of Southern California	1		1				1	
University of Texas at Austin	1		1					1
TOTAL	**58**	**25**	**19**	**14**	**13**	**14**	**15**	**16**

Note: The total number of awards won by each university from 2015 to 2020 are broken down by first, second, and third place, and then by the design challenge areas. Numbers under place awards and design challenge areas sum to the total number of awards respectively, and do not represent additional proposals.

Table 3. *Number of experts reported in each of the design packages submitted by the universities from 2015 to 2020*

University	Total Number of Award Winning Proposals	Number of Expert Interactions as mentioned in each of the winning design proposals	Median Number of Experts per proposal
Binghamton University – State University of New York	6	1 4 2 5 4 4	4
Embry-Riddle Aeronautical University	1	17	17
Florida Institute of Technology	1	8	8
Georgia Institute of Technology	1	5	5
Kansas State University Polytechnic Campus	1	6	6
Michigan Technological University	2	3 9	6
Old Dominion University	1	2	2
Penn State University	3	5 4 3	4
Purdue University	17	6 5 14 4 7 8 4 3 6 3 2 8 3 6 10 2 3	5
Roger Williams University	2	15 4	10
Rutgers, the State University of New Jersey	2	5 8	7
San Jose State University	1	NRF	NRF
Stevens Institute of Technology	2	1 9	5
The University of Texas at San Antonio	1	5	5
Tufts University	2	13 5	9
University of California, Berkeley	3	5 8 7	7
University of Colorado, Boulder	2	5 4	5
University of Massachusetts	1	2	2
University of Missouri – Columbia	2	13 3	8
University of Nebraska	1	6	6
University of Rhode Island	3	9 12 6	9
University of South Florida	1	6	6
University of Southern California	1	4	4
University of Texas at Austin	1	15	15
TOTAL	**58**	NRF: No Report Found	

Note: NRF means 'No Report Found', i.e., no design proposal was available in the ACRP winning design proposals archive. An expert interaction was considered as a valid count only if the contact was explicitly mentioned in the design proposal, or an exact number of survey respondents was reported in the proposal.

Figure 3 shows a comparison of the 24 universities by number of award-winning proposals and median number of experts interacted with per proposal, from 2015 to 2020. Purdue University has won 17 place awards between 2015 and 2020 and the median number of experts per proposal was 5. In contrast, Embry-Riddle Aeronautical University has won one place award between 2015 and 2020 and interacted with 17 experts during the project.

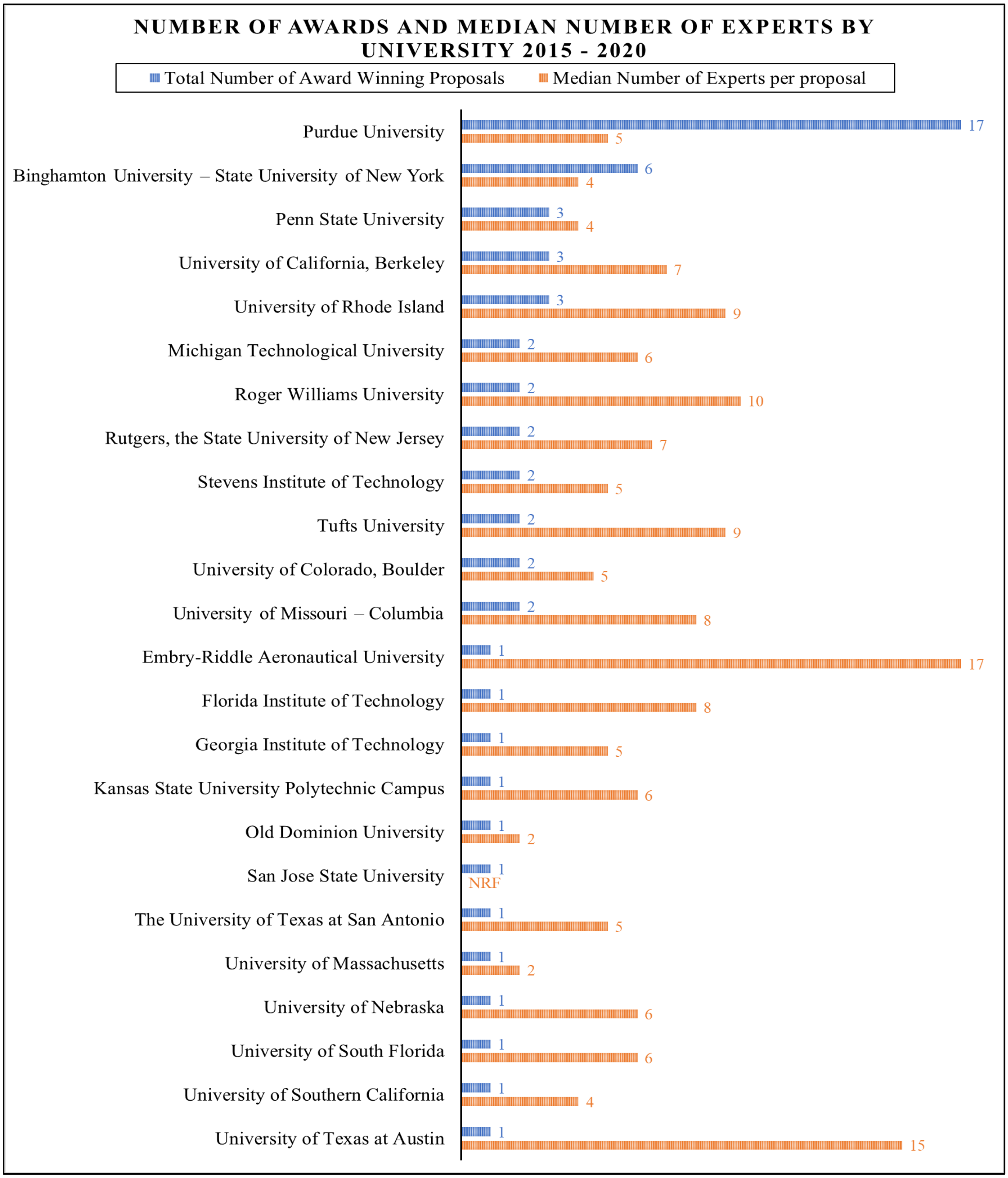


Figure 3. Number of award-winning proposals and median number of experts by universities

The research team read specific sections of the design proposals to identify the professional affiliations of the experts contacted by the student teams. Most of the student teams provided detailed information, such as job title, division or area of expertise, and organization name, of the experts when they were introduced in the report. In contrast, some teams chose to provide this information in 'Appendix A' of the report which includes a list of complete contact information for all advisors and team members [2]. A total of 344 experts were reported in the 57 winning design proposals from 2015 to 2020.

The researchers then identified the nature of the organization of the experts based on the information provided in the design proposals. The team determined two major organizations of the experts – 1) academic professors or university affiliated experts, and 2) Industry experts. Out of the total 344 experts, 55 (16%) of the experts were affiliated with universities. These included full-time professors, staff members, and doctoral or post-doctoral students (not part of the student teams). On the other hand, there were 256 (84%) experts that were from industry. Figure 4 shows the breakdown of professional affiliations of the experts. For example, airport affiliated experts such as operators, managers, or port authorities; airline affiliated experts; commercial pilots; experts from government agencies such as the FAA, the State Department of Transportation, or the U.S. Air Force; and others such as aerospace companies, construction companies, engineering companies, among others.

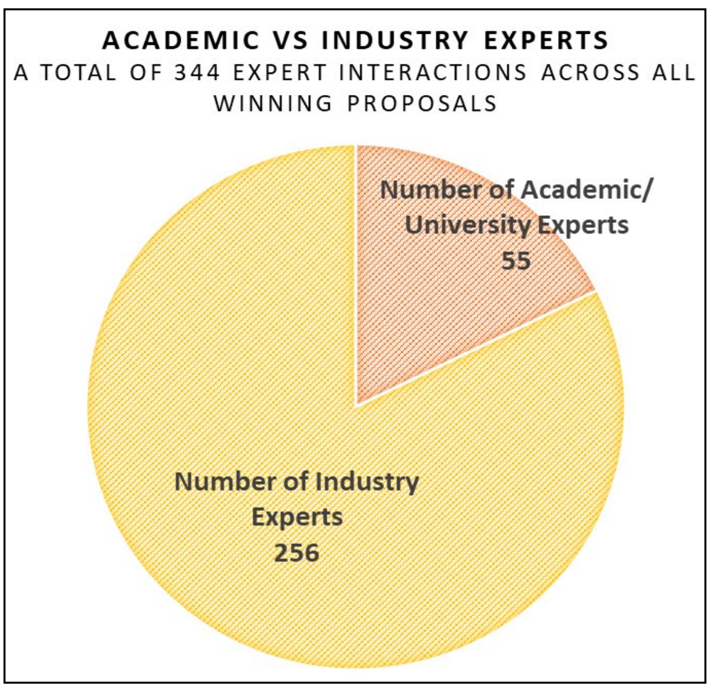


Figure 4. Professional Affiliations of the subject area experts

This section presents the data and results for research question 1 and question 2. From the data in Figure 3, one can see that there were many experts contacted by the ACRP design competition teams. From 2015 to 2020, the number of experts reported in the winning design proposals ranges from 1 to 17. Therefore, the research team wanted to study if the number of experts interacted with is statistically different for the place awards or on the design challenge areas. The research team counted the number of experts reported in each of the proposals across the three place awards and the four design challenge areas, and calculated the medians. The total number of experts, and the median number of experts per proposal are shown in Table 4.

Table 4. *Summary of number of experts by place awards and design challenge areas*

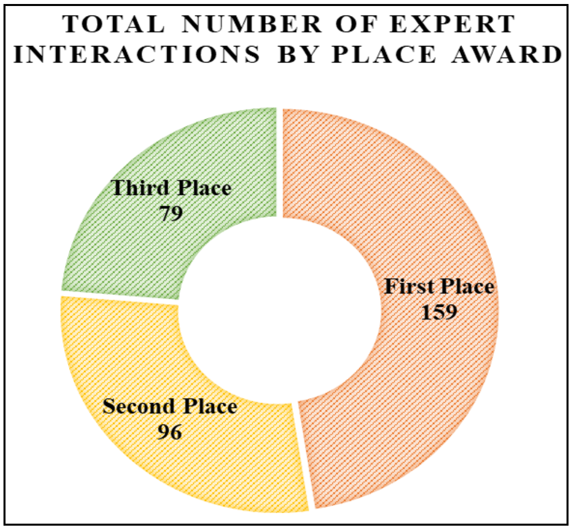
		Total Number of Reports	Total Number of Experts	Median Number of Experts
Place Award	First Place	25	159	6
	Second Place	19	96	5
	Third Place	14	79	5
Design Challenge	Airport Environmental Interactions	13	76	5
	Airport Management and Planning	16	92	5
	Runway Safety/ Runway Incursions/ Runway Excursions	15	97	5
	Airport Operations and Maintenance	14	74	5

RQ1 Experts by Place Awards. Figure 5(a) shows the total number of experts found in the first, second, and third place awards. The Kruskal-Wallis Test is used to determine whether the population median number of experts interacted with differed across the three place awards – first, second and third. The null and alternate hypotheses in the Kruskal-Wallis Test were:

H_0: All population medians are equal, i.e, population median number of experts on the winning first, second, or third place awards were the same.

H_1: At least one population median is different.

The results of the Kruskal-Wallis Test are shown in Figure 5(b). Using the data collected and an alpha of 0.05, the research team did not have enough evidence (p-value > 0.05) to reject the null hypothesis that the population medians are all equal. Therefore, the research team concluded that the population median number of experts may not be different for first, second and third place award winners. The research team plotted the median number of experts per design proposal per year, as shown in Figure 5(c). Over time, the median number of experts seems to have fallen in the third-place winning proposals, while it appears to be consistent in the first and second place winning proposals.



(a)

Descriptive Statistics

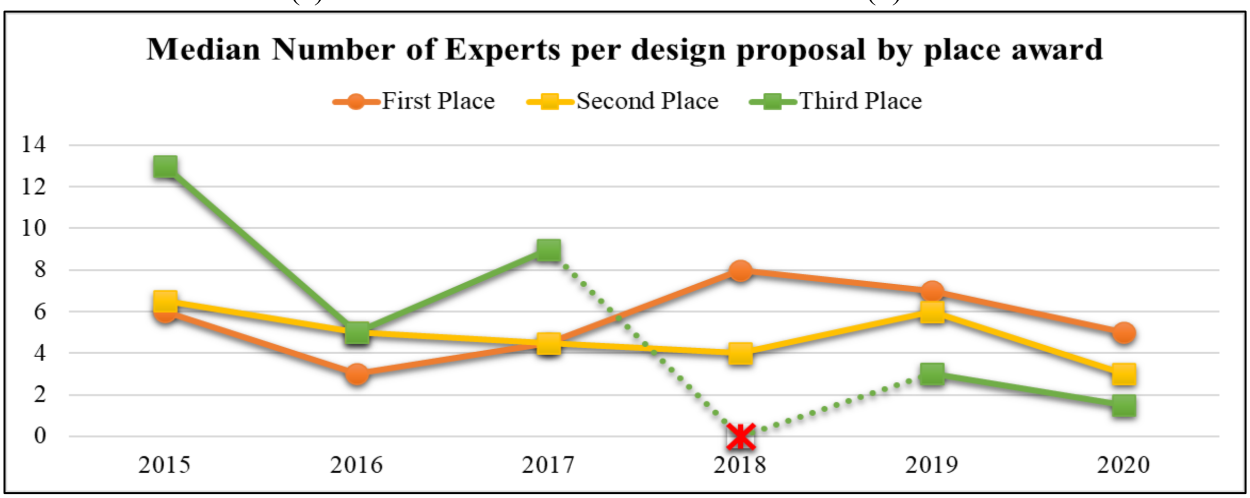
Award	N	Median	Mean Rank	Z-Value
First Place	25	6	31.7	1.10
Second Place	19	5	26.4	-0.84
Third Place	13	5	27.5	-0.36
Overall	57		29.0	

Test

Null hypothesis	H_0: All medians are equal
Alternative hypothesis	H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	2	1.25	0.535
Adjusted for ties	2	1.27	0.531

(b)



(c)

Figure 5 (a)-(c). Analysis of the number of experts by place awards

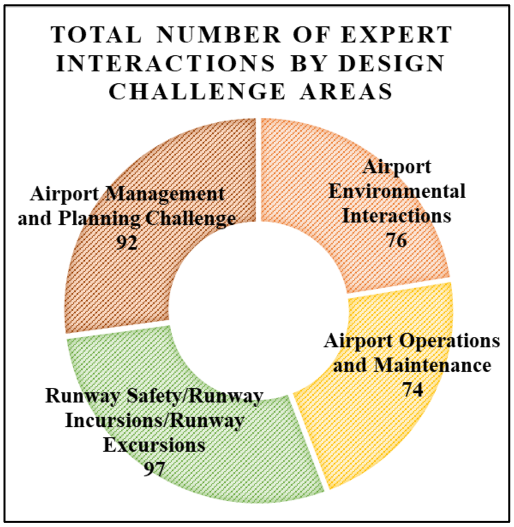
Note: Kruskal-Wallis result table shows that there was not enough evidence to reject the null hypothesis. The 'N' in the result table is the number of proposals in each of the categories. It is important to note that number of third place proposals is 13 and not 14. This is because one of the proposal packages that won the third-place award was not available on the ACRP online archive [10]. ✶In 2018, there were no third-place winners announced by ACRP [11].

RQ2 Experts by Design Challenge Areas. Figure 6(a) shows the *total* number of experts found in the four design challenge areas. The Kruskal-Wallis Test was used to determine whether the population median number of experts interacted with differed across the four design challenge areas: Airport Operation and Maintenance, Runway Safety/Runway Incursions/ Runway Excursions, Airport Environmental Interactions, and Airport Management and Planning. The null and alternate hypotheses in the Kruskal-Wallis Test were:

H_0: All population medians are equal, i.e, number of experts are the same across the four challenges areas.

H_1: At least one population median is different.

The results of the Kruskal-Wallis Test are shown in Figure 6(b). Using the data collected and an alpha of 0.05, the research team did not have enough evidence (p-value > 0.05) to reject the null hypothesis that the population medians are all equal. Therefore, the research team concluded that the population median number of experts may not be different across the winners in four design challenge areas. The research team plotted the median number of experts per design proposal per year as shown in Figure 6(c). The median number of experts interacted with appears to be consistent in each of the design challenge areas over time.



(a)

Descriptive Statistics

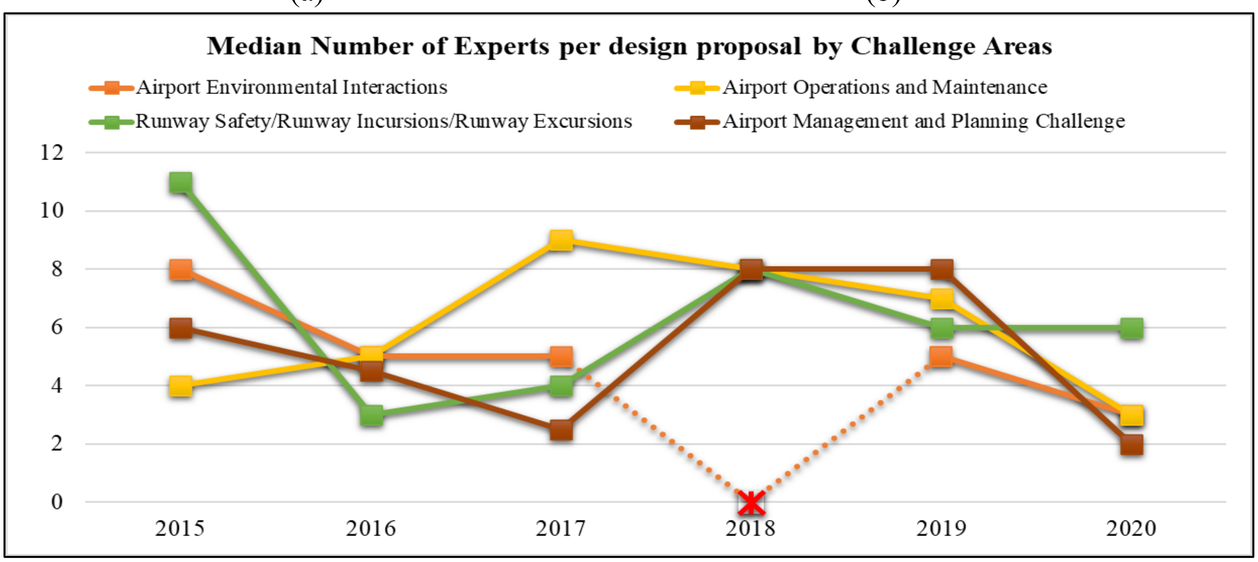
Design Categories	N	Median	Mean Rank	Z-Value
Airport Environmental Interacti	12	5	30.2	0.28
Airport Management and Planning	16	5	26.9	-0.60
Airport Operations and Maintena	14	5	28.8	-0.06
Runway Safety/Runway Incursions	15	5	30.5	0.42
Overall	57		29.0	

Test

Null hypothesis H_0: All medians are equal
Alternative hypothesis H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	3	0.46	0.928
Adjusted for ties	3	0.46	0.927

(b)



(c)

Figure 6 (a)-(c). Analysis of the number of experts in the four design challenge areas.

Note: the Kruskal-Wallis result table shows that there was not enough evidence to reject the null hypothesis. The 'N' in the result table means the number of proposals in each of the categories. It is important to note that number of proposals in Airport Environmental Interaction is 12 and not 13. This is because one of the proposal packages that was submitted in this design challenge category was not available on the ACRP online archive [10]. * In 2018, there were no winning teams in the Airport Environmental Interactions challenge area [11].

RQ3 Themes by Place Awards. This section presents the thematic results by design placement (First, Second, and Third place) to understand if there are similar or different themes across the place awards with regard to the expert interactions. Thematic results were identified by carefully reading two sections of the design submittals that relate to the interactions with industry experts. The two sections are required per the design competition guidelines [2] and the evaluation criteria [7].

- Evidence of effective interaction with airport operators and industry experts in the design process must be included. Students may use a list of 'Expert Advisors' provided by the ACRP or they may find other subject matter experts and show proof of interaction. The section carries 12 of 130 points for the design.
- Appendix E Question 4 addresses the students' experiences with the expert interactions. "Was participation by industry in the project appropriate, meaningful, and useful? Why and Why not?" [9]. Appendix E is one of the six required appendices for the competition submittals.

Figure 7 shows common themes identified in all three categories of designs (first place, second place and third place), then, themes for each category. Additional information on these affinity diagrams are in the appendix.

Discussion

Interactions between industry experts and students are an important part of a design course. Previous studies have shown that students, education institutions and sponsoring companies would all benefits from collaborations between industry and education institutions [3], [4], [5]. The annual Airport Cooperative Research Program (ACRP) Design Competition provides an opportunity for students to undertake a course projects and adds the requirement that students must show evidence of interactions with industry experts.

The ACRP is designed to focus on solving problems in the airports industry. Proposals are submitted by students in any US collegiate educational program for undergraduate or graduate students. Design proposals have been submitted by students in computer science, engineering, human factors, management, psychology programs, among others.

In this study, the researchers collected 57 winning design proposals from the ACRP Design Competition website and analyzed the reports with the objective of identifying the number of experts interacted with in four categories of the ACRP design competition, and the underlying themes in industry interactions reported in the winning design proposals. Of the 57 design proposals that won first, second, and third place awards from 2015 to 2020, the research team found that 84% of the total number of experts that interacted with students were affiliated with industry, while 16% were affiliated to universities or academia. These 57 design proposals were from 24 different universities.

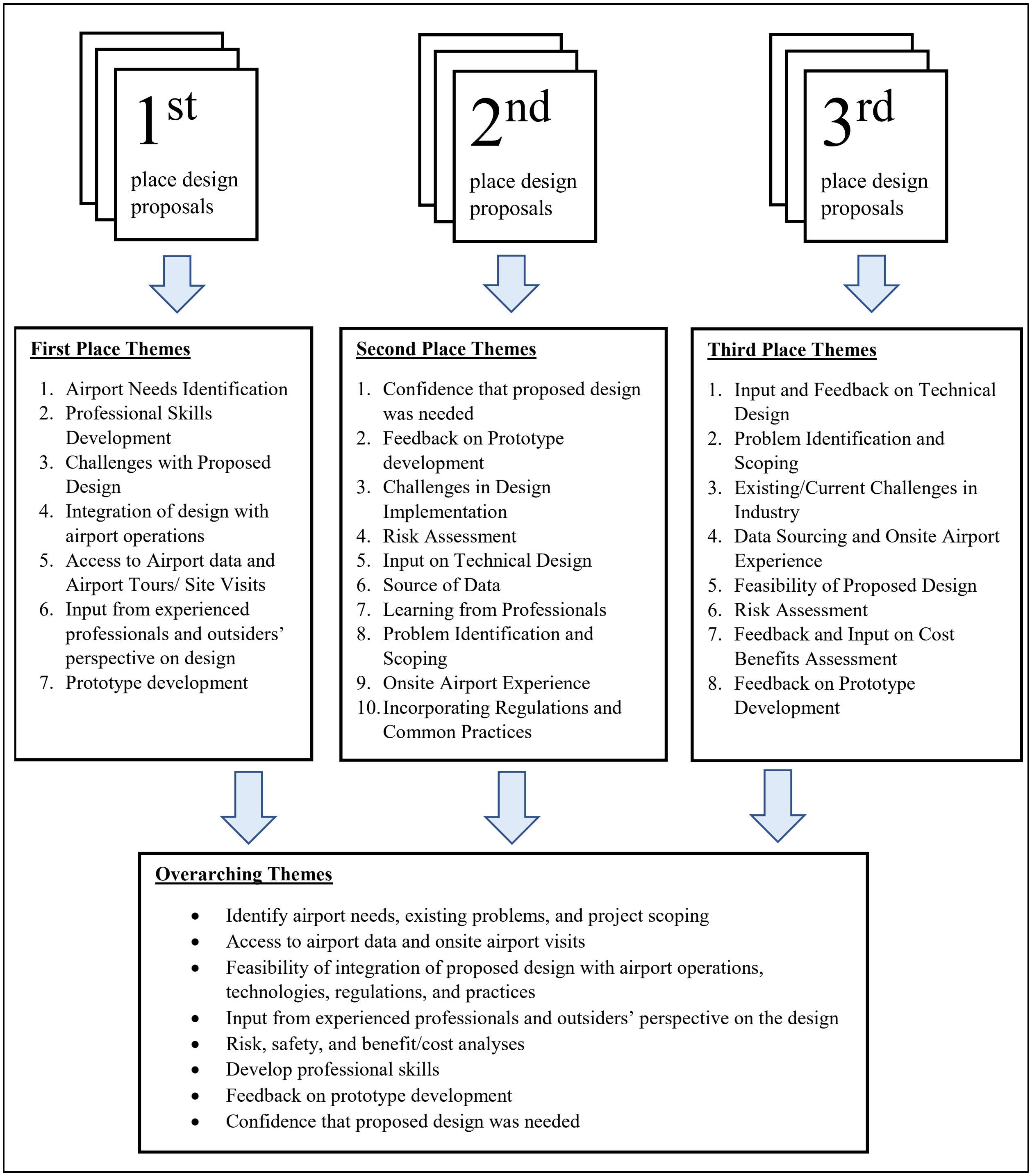


Figure 7. Themes in first, second, and third place design proposals.

Three research questions were answered in the study. To summarize the results in this discussion, each question is addressed separately.

Research Question 1. Is there a statistically significant difference in the number of experts interacted with across first, second, and third places?

In this study using an alpha =0.05, the test for significance did not show a difference in the population median number of experts interacted with across these award winners. It may be tempting to presume that this means that the number of experts may not matter; however, there are at least three additional questions that may be asked.

First, do these award-winning proposals differ from the non-award winners in terms of the number of experts interacted with? Because the non-award-winning proposals are not available on the website, the research team could not conduct this type of analysis.

Second, is the quality of the interactions or frequency of interactions considered? Details on the quality and frequency of interactions are not part of the evaluation criteria and it is not reported consistently in the award-winning proposals. Practically speaking, one might presume that the higher quality and the higher number of interactions might improve the overall quality of the design proposal.

Third, does the timing of the interactions during the development of the design proposal make a difference? Interacting during scope and idea development may have a different nature than interacting during final design stages. Additionally, the later it is in the design process, the more difficult and time-consuming it is to accommodate design changes. Finding out that a team's idea is not practical in the early weeks of design development may be more easily accommodated; while in the final design change, this information may be frustrating for both the students and experts.

Research Question 2. Is there a statistically significant difference in the number of experts interacted with across the four design challenge areas?

In this study using an alpha =0.05, the test for significance did not show a difference in the population median number of experts interacted with across the four design challenges. The four design challenge areas may present issues that are not known to all experts; e.g. the experts in airport environmental regulations may be different individuals than the experts in airport excursions and incursions. The competition website provides resources to help student teams contact experts in specific challenge areas; many of these experts overlap.

Research Question 3. What are the reported benefits of the interactions with industry experts in the design proposals?

In this study, the thematic analysis indicates that the reported benefits of interacting with experts had similar themes across the winning proposals. The research team did not find any noticeable differences among the winning proposals in first, second, or third places. Using affinity diagrams, the research team identified eight overarching themes:

- Identify airport needs, existing problems, and project scoping
- Access to airport data and onsite airport visits
- Feasibility of integration of proposed design with airport operations, technologies, regulations, and practices
- Input from experienced professionals and outsiders' perspective on the design
- Risk, safety, and benefit/cost analyses
- Develop professional skills
- Feedback on prototype development
- Confidence that proposed design was needed

Most of these themes correspond to the design process from ideation through prototype development. Specific to designs to be implemented at airports, a common theme was access to real airports and real airport data. As airport researchers ourselves, we thought it was refreshing that teams from multiple disciplines appreciated airport onsite visits and the intangible information that can be gained. With a growing number of winning design proposals that include sustainability [12], the experts may need to represent a wider range of knowledge in sustainability as it effects aviation and airports.

Conclusion

Faculty in engineering, technology and other technical courses may desire to provide an opportunity where students can engage and exchange ideas with industry experts. Time constraints and the pressure to cover specific course materials in a semester may make actually facilitating interactions with experts a difficult thing to do. The annual Airport Cooperative Research Program (ACRP) Design Competition provides an opportunity for students to undertake a project that has the requirement that students must show evidence of interactions with industry experts. Although the competition is designed to focus on solving problems in the airports industry, the competition does attract students from many types of programs and not only aviation.

In this study, the researchers collected 57 winning design proposals from the ACRP Design Competition website and analyzed the reports with the objective of determining the perceived value of interactions with airport operators and other industry experts. The researchers found that the *number* of experts interacted with is not statistically different across the three place awards and the four design challenge areas. However, the research was limited to the winning design proposals available on the ACRP website, and researchers had no access to other design submittals. Therefore, the researchers could not determine if number of experts has any impact on winning a place award in the ACRP design competition. The researchers aimed to identify commonalities and differences of the underlying themes in the reported expert interactions. This effort resulted in eight themes. During the design process, experts provided feedback on ideas, needs, feasibility, benefit-cost analysis, safety, regulations, implementation, and prototype development, and other technical issues. Professional skill development was mentioned in team reports as was increased confidence that the proposed design was needed.

Future studies might delve into the particular procedures that teams use during interactions, methods to increase the quality of interactions and frequency of interactions, and the effect of starting interactions earlier in the design process. Development of personal skills through interactions with experts in industry may also be explored.

References

[1] *Airport Cooperative Research Program (ACRP).* University Design Competition. [Online] https://vsgc.odu.edu/acrpdesigncompetition/ [Accessed: March 5, 2021].

[2] *Airport Cooperative Research Program (ACRP)*. University Design Competition for Addressing Airport Needs. 2020-2021 Design Competition Guidelines. [Online] https://vsgc.odu.edu/acrpdesigncompetition/wp-content/uploads/sites/3/2020/08/2020-ACRPD-small.pdf [Accessed: March 5, 2021].

[3] W. Eric Wong, "Industry Involvement in an Undergraduate Software Engineering Project Course: Everybody Wins" in *Software Engineering Outreach: Industry, K-12: Proceedings of the 120th ASEE Annual Conference and Exposition,* Atlanta, GA, USA, June 23-26, 2013, PaperID #6912

[4] C. O. Ruud and V. J. Deleveaux, "Developing and conducting an industry-based capstone design cours*e" in Proceedings Frontiers in Education 1997 27th Annual Conference. Teaching and Learning in an Era of Change*, Pittsburgh, PA, USA, 1997, pp. 644-647 vol.2, doi: 10.1109/FIE.1997.635886.

[5] S. Gorka, J. R. Miller, and B. J. Howe, "Developing realistic capstone projects in conjunction with industry" *in Proceedings of the 8th ACM SIGITE conference on Information technology education (SIGITE '07)*. Association for Computing Machinery, New York, NY, USA, pp. 27–32, 2007. DOI:https://doi.org/10.1145/1324302.1324309

[6] *Transportation Research Board (TRB).* Airport Cooperative Research Program. [Online] http://www.trb.org/ACRP/ACRP.aspx [Accessed: March 5, 2021].

[7] *Airport Cooperative Research Program (ACRP)*. 2020-2021 Evaluation Criteria for University Design Competition for Addressing Airport Needs. [Online] https://vsgc.odu.edu/acrpdesigncompetition/evaluation-2/ [Accessed: March 5, 2021].

[8] *Airport Cooperative Research Program (ACRP)*. Resources. [Online] https://vsgc.odu.edu/acrpdesigncompetition/resources/ [Accessed: March 5, 2021].

[9] *Airport Cooperative Research Program (ACRP)*. Appendixes. Appendix E: Evaluation of Educational Experience Provided by the Project. [Online] https://vsgc.odu.edu/acrpdesigncompetition/wp-content/uploads/sites/3/2018/03/Appendix-E_design-competition.pdf [Accessed: March 5, 2021].

[10] *Airport Cooperative Research Program (ACRP)*. 2015 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2015-competitionwinners/ [Accessed: March 5, 2021].

[11] *Airport Cooperative Research Program (ACRP)*. 2018 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2018-competitionwinners/ [Accessed: March 5, 2021].

[12] M.E. Johnson, Y. Gu, and L E. Holtaway, "Aerospace: Inclusion of Sustainability Analysis in a National Air-port Design Competition," in *Proceedings of the 126th ASEE Annual Conference and Exposition – Aerospace Division Technical Session 2*, Salt Lake City, Utah. June 23-27, 2018. Doi.10.18260/1-2—30640

[13] *Airport Cooperative Research Program (ACRP)*. 2020 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2020-acrp-design-competition-winners-announced/ [Accessed: March 5, 2021].

[14] *Airport Cooperative Research Program (ACRP)*. 2019 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2019-competitionwinners/ [Accessed: March 5, 2021].

[15] *Airport Cooperative Research Program (ACRP)*. 2017 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2017-competitionwinners-3/ [Accessed: March 5, 2021].

[16] *Airport Cooperative Research Program (ACRP)*. 2016 Competition Winners. [Online] https://vsgc.odu.edu/acrpdesigncompetition/2016-competitionwinners/ [Accessed: March 5, 2021].

APPENDIX. Detail Level Affinity Diagram

First Place Affinity Diagram

Theme 1: Airport Needs Identification and Current Challenges	
▪ Identifying a gap/area of needs/challenges in airports ▪ Problem scoping/Narrowing down ideas ▪ Existing technologies in design area and their limitations ▪ Scoping design to fit airport needs	▪ Aligning design with airport/industry needs ▪ In-depth background knowledge on design area ▪ Identifying deeper questions on the topic ▪ Confirm need for technology ▪ FAA and other regulations on proposed design
Theme 2: Professional Skills Development	
▪ Developing business communication skills	▪ Experts feedback gave students confidence and encouragement
Theme 3: Challenges with Proposed design	
▪ Potential challenges with proposed design ▪ Possible challenges with use of proposed design ▪ Alternative solutions to proposed design	▪ Cost estimates for design materials/prototype ▪ Feedback on initial design ▪ Professional input on technical parts of design
Theme 4: Integration of Design into Airport Operations	
▪ Understanding incentive of proposed design to airport operators ▪ Potential impact of design on airport management ▪ Industry practices that may not be reported	▪ Risk assessment on proposed designs ▪ How proposed designs can improve airport operations/ Feasibility?? ▪ Integrating design with existing airport technology ▪ Consideration for use of design by different airport users
Theme 5: Access to Airport Data and Airport Tours	
▪ Transfer knowledge from classroom to industry ▪ Airport visit	▪ Filling gaps that were not found in literature reviews ▪ Access to data that is not available publicly/Insider knowledge
Theme 6: Input from Experienced Professionals and Outsiders Perspective on Design	
▪ Outsiders perspective ▪ Guidance throughout the design process (with non-university partnerships) ▪ Connections to other industry experts	▪ Perspectives of different airport professionals ▪ Learning from experienced professionals ▪ Perspectives of different airport professionals
Theme 7: Prototype development	
▪ Potential industry partners for design implementation	▪ Developing and testing prototype

Second Place Affinity Diagram

Theme 1: Confidence that Proposed Design was Needed	
▪ Confidence that design was feasible ▪ Confidence that design would be helpful ▪ Added confidence on design viability ▪ Feedback gave students confidence	▪ Confidence that design was appropriate and needed ▪ Confidence in proposed design ▪ Confidence that design was feasible
Theme 2: Feedback on Prototype development	
▪ Feedback on prototype ▪ Feedback on usefulness of design ▪ Design feasibility and potential for commercialization ▪ Provided equipment to develop prototype	▪ Provided venue to test prototype ▪ Resources/Site for prototype testing ▪ Provided opportunity to test prototype
Theme 3: Challenges in Design Implementation	
▪ Understanding potential operational benefits ▪ Possible challenges in using design ▪ Applicability of design ▪ Gauging impact of design on industry ▪ Challenges of using proposed design ▪ Integrating design with other airport operations ▪ Challenges in design implementation ▪ Insight on incorporating design into current technologies	▪ Project feasibility ▪ Feasibility and novelty of proposed design ▪ Technical feasibility of design ▪ Areas where design would be most useful ▪ Practicality of proposed design ▪ Possible loopholes/downsides of adopting proposed design ▪ Possible geographic areas where design might be applicable
Theme 4: Risk Assessment	
▪ Feedback on cost analysis, environmental analysis and risk assessment ▪ Design risk considerations ▪ Risks associated with proposed design ▪ Cost/financial estimates for design implementation	▪ Cost estimates of proposed design relative to traditional approach ▪ Security measures associated with design ▪ Risk assessment insight
Theme 5: Input on Technical Design	
▪ Technical design input ▪ Areas of improvements ▪ Refining design based of experts' opinions and feedback ▪ Potential areas of improvement ▪ Experts provided feedback during design process ▪ Identify various aspects of design ▪ Provided feedback throughout the project (Non-University partners)	▪ Provided input on design methodology ▪ Provided input and feedback based on experience ▪ Feedback and guidance in design ▪ Experts helped identify challenges in design ▪ Provided ideas for improving design ▪ Provided technical assistance ▪ Helped with technical aspects of design ▪ Possible areas of improvement

▪ Provided technical knowledge on proposed design ▪ Feedback on design	▪ Feedback on developing a user-friendly design ▪ Experts were useful and important in developing design
Theme 6: Source of Data	
▪ Provided data to design prototype and run simulations ▪ Obtaining data not available elsewhere ▪ Simulation data ▪ Provided data for protypes testing	▪ Data necessary for experimental study ▪ Additional material not available through lit review ▪ Data maps
Theme 7: Learning from Professionals	
▪ Experts shared personal experiences in the problem area ▪ Design improvements incorporated experts' opinions ▪ Benefited from interacting with experienced professionals ▪ Positive interactions between students and professionals ▪ Benefited from sharing experience with experienced professionals ▪ Experts helped identify other subject matter experts (referrals)	▪ Understanding problem in context from experienced professionals ▪ Experts provided a different perspective on the design ▪ Understanding challenges experienced by professionals ▪ Experts provided insights from a professional point of view ▪ Provided insight from a business perspective
Theme 8: Problem Identification and Scoping	
▪ Problem/ design scoping ▪ Provided deeper understanding of problem area ▪ Identifying potential constraints in design area ▪ Scoping design after interactions with experts ▪ Narrowing design from broad to specific area ▪ Narrowing down challenges experienced by professionals ▪ Scoping design ▪ Topic scoping and narrowing topic	▪ Narrowing focus of problem ▪ Scoping prior to design ▪ Scoping of topic area ▪ Need for design in industry ▪ Choosing a topic ▪ Redefining concepts ▪ Clarify concepts in area of design ▪ Identifying potential constraints/ areas of improvement
Theme 9: Onsite Airport Experience	
▪ Access to airport ▪ Site visit to airport facilities ▪ Provided hands on experience ▪ Touring airport facilities and interacting with professionals at work	▪ Experience with everyday airport operations ▪ Partnerships with local airport (Non-University partners)
Theme 10: Incorporating Regulations and Common Practices	
▪ Understanding existing operations	▪ Learning about industry

▪ Understanding current technologies and areas of improvement ▪ Insight on industry practices ▪ Current industry practices related to design ▪ Feedback on Federal Aviation Administration (FAA) regulations on proposed designs	▪ In-depth understanding of industry challenges ▪ Industry challenges ▪ Additional details on industry operations – processes and procedures ▪ Industry regulations on proposed design and the impact of regulations
Other Themes Identified	
▪ Provided platform to learn about aviation industry ▪ Benefited from experience ▪ Different from traditional school projects	

Third Place Affinity Diagram

Theme 1: Input and Feedback on Technical Design	
▪ Usefulness of proposed technology/design ▪ Feedback on proposed design ▪ Identify errors in design ▪ Impact/effects of design on exiting airport systems ▪ Missed aspects of design ▪ Potential shortcomings in design	▪ Proposed changes to improve design ▪ Regulations related to design ▪ What to avoid when developing design ▪ Creating a realistic and innovative solution ▪ Initial design idea ▪ Input on initial design ▪ Refining design goals ▪ Suggestions for design changes/improvements
Theme 2: Problem Identification and Scoping	
▪ Background knowledge on the topic ▪ Current practices ▪ Directing design to solve specific industry problem ▪ Identify problem areas ▪ Identify specific industry challenge/ Existing challenges	▪ Identifying specific problem areas ▪ Identifying the weaknesses/drawbacks of proposed system ▪ Narrowing down problem
Theme 3: Existing/Current Challenges in Industry	
▪ Challenges with existing technologies ▪ Challenges with use of technology ▪ Current challenges ▪ Current technologies and their challenges ▪ Existing technologies ▪ Existing technologies in the problem area ▪ Challenges with current industry practices	▪ Integrating design into exiting systems ▪ Integrating system with existing technologies. ▪ Integration with existing airport systems ▪ Understanding the needs for different airport workers

▪ Compliance with industry regulations and standards	
Theme 4: Data Sourcing and Onsite Airport Experience	
▪ Access to airport data ▪ Onsite experience ▪ Onsite/Airport experience	▪ Site tour / hands on experience ▪ Site/Airport visit
Theme 5: Feasibility of Proposed Design	
▪ Concerns/drawbacks with proposed technology/design ▪ Feasibility of design ▪ Feasibility of the design	▪ Feedback on feasibility of technology ▪ Possible changes/ Feedback on feasibility of design
Theme 6: Risk Assessment	
▪ Identifying risks in proposed design ▪ Potential dangers of using a proposed design	▪ Recommendations for safety assessment of design Safety concerns on design
Theme 7: Feedback and Input on Cost Benefits Assessment	
▪ Conducting cost benefits assessment ▪ Cost benefit analysis ▪ Cost of design	
Theme 8: Feedback on Prototype Development	