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Date: May 13, 2016
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From: Gary Lichtenstein (QED),
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Subject: Fluid Power Challenge survey analysis

Background

This report summarizes survey results from the Fluid Power Challenge (FPC), an NFPA sponsored event for 8th graders designed to heighten awareness of fluid power and spark interest in engineering and fluid power careers specifically.

The FPC is a two-day event. Students first participate in a Workshop Day, in which they are exposed to principles of fluid power through construction of a pneumatic lifter. They leave the workshop with a kit for building a device that will be the focus of the competition on Challenge Day. Students work with the kits for a few weeks before returning for Challenge Day. On Challenge Day, students must build the device they have been working with through the kits, and then demonstrate that the device works.

NFPA has designed and distributed a pre- and a post-survey to assess how the FPC affects students' attitudes and understanding of fluid power (see Appendix A). Students complete a pre-survey at the beginning of Workshop Day and a post-survey at the end of Challenge Day. The surveys are comprised of nearly identical items, with initial questions probing students' familiarity with fluid power and fluid power careers, and subsequent questions focused on specific fluid power concepts and formulas. The post-survey asks students to rate the event. NFPA had surveys from several years that had not been analyzed and sent those to QED for analysis.

Method

Surveys were in hard copy from FPCs that took place in three or four years up to 2015. QED received 873 pre-surveys and 775 post-surveys. Surveys were not matched to student, school, or organized by year. QED separated surveys in to pre- and post and numbered each survey. We then used a random number generator to randomly select a minimum of 33% of pre- and post-surveys to analyze. Sampling theory predicts that random selection of this many surveys can be expected to yield an accurate estimate of all survey results.

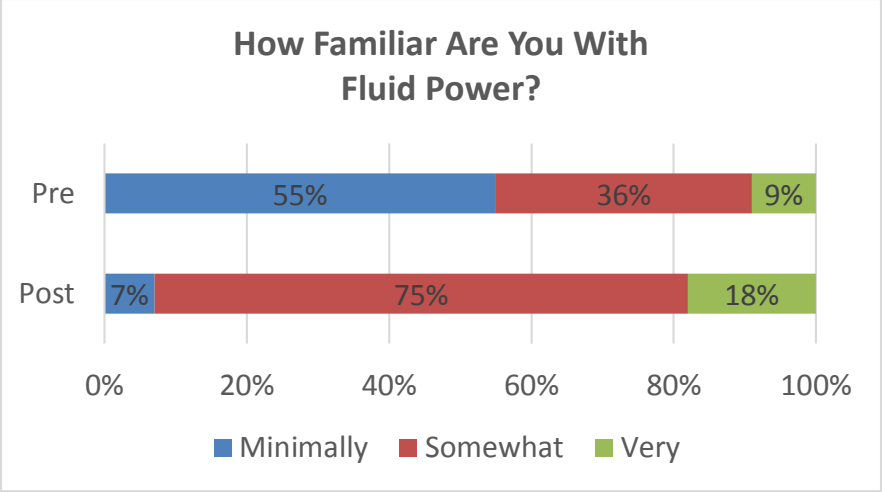
The first two items of the pre-survey ask how familiar a student is with fluid power and how familiar a student is with fluid power careers. The remaining ten items ask very specific questions about fluid power concepts and formulas. Some students may be exposed to these concepts in their science and engineering classes, and some may have experienced the suggested FPC pre-lesson provided by NFPA. However, it was impossible to know whether students had prior exposure through these or other means. Therefore, right answers could not be attributed to prior instruction, and wrong answers could not be attributed to lack of exposure or failure to learn taught concepts. Because of this, only the first two pre-survey items were analyzed.

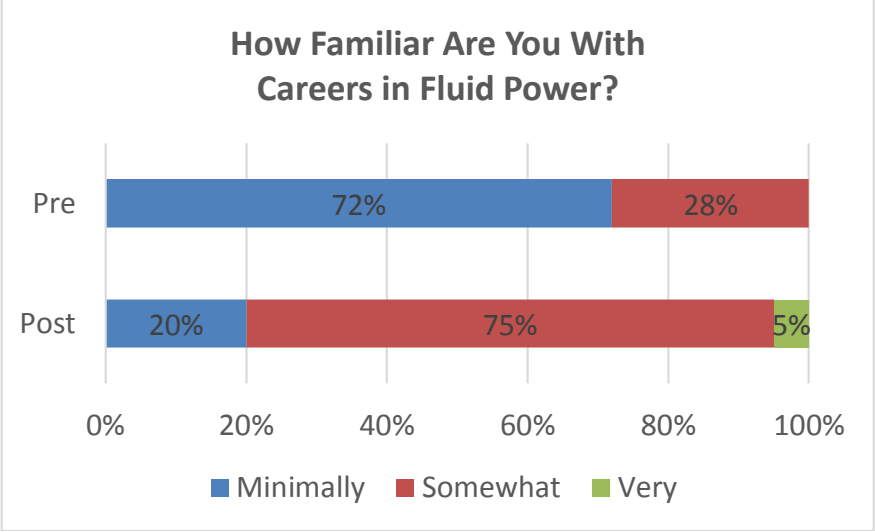
The post-survey is comprised of 17 items. Items 1-3 probe the student's familiarity with fluid power and fluid power careers and his or her interest in a fluid power career. Items 3-6 ask students to rate how engaging the FPC was (from 1=*dull* to 5=*exciting*) and why. Items 7-16 ask the same specific questions about fluid power concepts and formulas as appear in the pre-survey. The final item is for open-ended *Comments*.

QED entered data from 287 pre-surveys and 341 post-surveys—all randomly selected. We can't know how many surveys were returned compared to those distributed. However, nearly 100% of respondents answered the two opinion questions on the pre-survey and the six opinion questions on the post-survey (responses to concept and formula items are analyzed below), suggesting good engagement from those who did complete a survey. We compared pre- and post-survey responses to *familiarity with fluid power and fluid power careers*, examined *FPC ratings*, and assessed post-survey items related to *fluid power concepts and formulas*.

Familiarity With and Interest in Fluid Power Careers

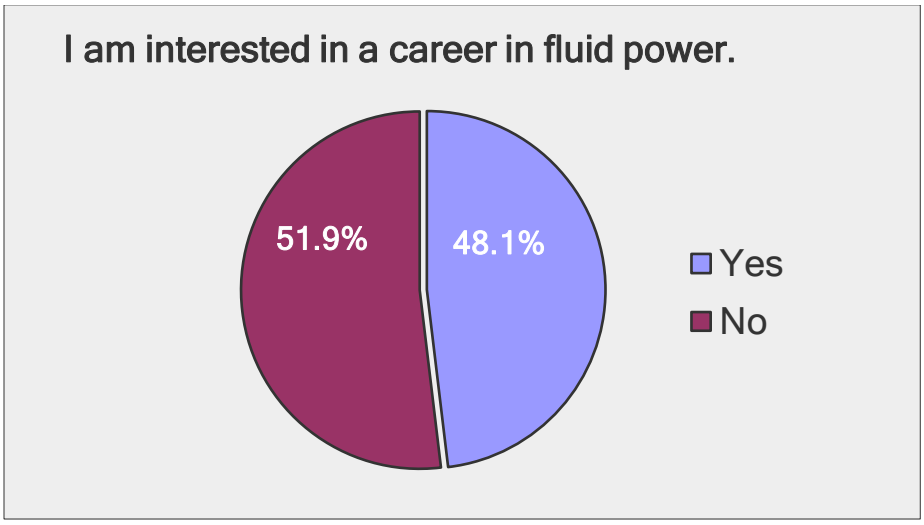
Significant shifts occurred from the pre- to the post-survey in terms of students' familiarity with fluid power and fluid power careers. Whereas 55.4% of students reported *no* or *minimal* familiarity on the pre-survey, only 7.4% reported *no* or *minimal* familiarity on the post-survey. On the post-survey, 92.6% reported being *somewhat or very familiar* with fluid power, compared to 44.5% on the pre-survey (see charts below).





Surveys showed significant shifts regarding students' familiarity with fluid power careers. On pre-surveys, 71.4% of students reported *no* or *minimal* familiarity, compared with 19.9% on the post-survey. Eighty percent of post-survey respondents reported they were *somewhat* or *very* familiar with fluid power careers. *Note: both items (*fluid power *and* career familiarity*) were rated on a 5-point scale (1=Not At All; 5=Very); for these analyses, response options 1 and 2 were combined to create a* No or Minimally *variable, and 3 and 4 were combined to create a* Somewhat *variable.*

Students were split nearly evenly on the post-survey between those interested in a fluid power career (48%) and those who aren't (52%).



Interestingly, 80% of students provided a reason why, which is rare on surveys, especially among middle-schoolers. This suggests engagement with FPC and the survey itself. Reasons for interest in fluid power centered on it being interesting and exciting. Sample comments include:

- *I am interested in how fluid power can make other things move and save more problems.*
- *I enjoy learning new things about hydraulics and pneumatics*
- *It's creative.*
- *It's awesome.*
- *I enjoy engineering.*
- *Building things is fun.*
- *Because I found it very fascinating how fluid power can be used to do so many things.*
- *It's a new field with many new possibilities.*
- *It seems like a great help for the future of America.*

The majority of comments were from those not interested in fluid power, either because they weren't good at it, they found it stressful, or they have other career goals. Representative comments include:

- *It's a tough career.*
- *I'm not interested in it.*
- *I want to be a doctor.*
- *I want to be a therapist.*
- *I'm more for sports.*
- *I think I would prefer a job with less stress.*
- *Not a fit.*
- *I am more interested in a different part of engineering.*
- *It's a lot harder than I thought.*
- *Boring.*
- *I found it stressful with water everywhere.*
- *It's very complicated and confusing.*
- *I'm not too good at it.*

Summary: Fluid Power Interest & Careers
Students made significant shifts in their awareness of and interest in fluid power from the pre- to the post survey. At the post-survey, 64% felt that they knew a good deal about fluid power, compared to 9% on the pre-survey. On the post-survey, the majority of responses to the question related to awareness of fluid power careers was *Somewhat* (47%). We don't know the extent to which fluid power careers is discussed at the Workshop and Challenge days. However, since making students aware of fluid power careers is a main objective of the FPC, this is a facet of the workshop to consider strengthening.

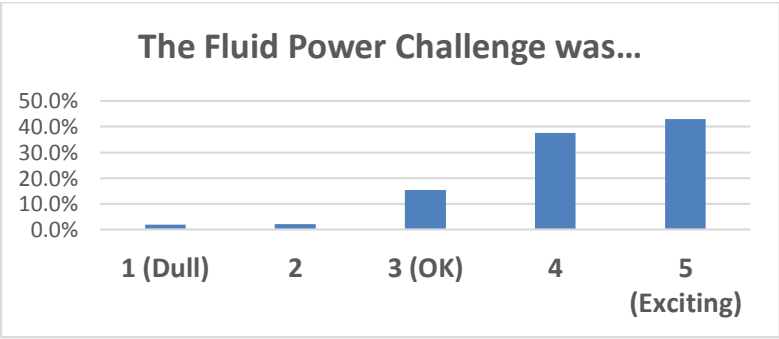
Related to the goal of making students aware of fluid power careers, QED recommends that more questions be added to assess students' understanding of fluid power careers, including what jobs exist in the fluid power industry. This sort of item could be followed up on in the question that relates to interest in a fluid power career—what job in fluid power interests the student? Responses to these questions could suggest ways to highlight different fluid power jobs during the FPC, as well as design follow-up information and/or programs.

Half of respondents expressed an interest in a fluid power career. This item could yield more information if the response options were expanded. Currently, the only options are *Yes* or *No*. Using the same scale as prior items would help NFPA gauge the level of interest students have. If job types were delineated in the prior question, as suggested above, NFPA would get a sense about which jobs in the fluid power sector appeal to participants. Finally, although NFPA suggests that two girls be recruited to each FPC team, a gender item is not currently included on the survey. Crossing all these questions by gender would yield valuable information to NFPA and to teachers about how boys and girls experience the FPC, as well as ways to follow up the FPC event.

Fluid Power Challenge Ratings (Post-Survey)
The mean rating for the FPC was 4.1 (1=Dull; 5=Exciting). The chart below shows an overwhelmingly positive response to the event, especially considering that students are 8th graders—a tough age to engage.

Ratings of the event, although predominately high, were influenced by students' interest in a fluid power career. Those who answered *Yes* regarding an interest in fluid power were moderately more likely to rate the FPC higher than those who answered *No* (r^2=0.37, p=.000).

That being said, there was no correlation between a students' interest in fluid power as a career and whether the student would recommend the FPC to friends. Only 15% said they would not recommend FPC to friends, while the remaining 85% responded that they would. QED was impressed with the reasons students made the recommendations they did, samples of which are shown in the table below.



When asked *What was the best thing about the FPC*, the most common answer was being able to build something, which was listed by 36% of respondents. The second-most popular answer was "teamwork" (27%). Other responses included the overall experience, designing, the challenge, and the food.

I would recommend FPC to any student I know (Representative responses)	
YES (85%)	NO (15%)
It's fun.	*Not everyone would be interested.*
It's a great learning experience.	*It's not what it seems to be.*
It was fun just to build with friends.	*They're not that good at building.*
It's a good opportunity.	*Not fun, very stressful.*
Because they can learn a lot	*Overwhelming stress*
So they can feel excited and get to learn a new thing.	*Not all students I know would be able to handle the challenge.*
It would be useful to know things like this in the real world.	*Because some students don't like building or can't or just don't understand.*
It gets you smarter.	*Maturity*
It's a good science project.	*It takes a lot of patience.*
Some might want to be an engineer in their future.	*It is stressful for some people's minds. I'd rather not induce pressure on them.*
It was a new and different experience for all of us, working together with others.	*Because some aren't interested in engineering and you need focus skills.*
It teaches teamwork and problem solving skills.	
It makes you think differently.	
It's a challenging and innovative project that helps you bond with your team.	
A lot of fun and expands leadership skills.	

The last item in the survey simply says *Comments?* Approximately one-third of respondents provided comments—a lot for 8th graders. Most were extremely positive. Examples include:

- *Something you can use to help you.*
- *I really enjoyed working in fluid power.*
- *It was a fun and great experience.*
- *The fluid power challenge was fun but stressful.*
- *Lunch was delicious.*
- *This was a new experience for me. I never thought it could be that fun.*
- *This was a very fun thing to do and I was happy to be a part of it.*
- *Do it next year!*
- *The challenge was fun and challenging and this experience will help me in the future.*
- *This club was the most fun I ever had.*
- *Thank you! (Several responses)*
- *The competition was an amazing experience for students like us.*
- *I would definitely do this again.*

Suggestions and negative comments should be noted as well:

Understanding/Level of Challenge

- *I kind of still don't understand all of this.*
- *I think I failed.*
- *lol--sorry for not knowing stuff.*
- *Our group needed 5 minutes but we didn't have that.*
- *Make directions more simple to understand.*
- *I'm not good with breaking down big words (items 11-16)*
- *A week of more time would be perfect.*
- *Needed more of a visual.*
- *I didn't really learn the theory behind how it all works.*

Team Dynamics

- *Great for team-building skills; a strong commitment to teammates is also needed. If all members are not committed, the team is only as strong as their weakest member.*
- *There were a lot of challenges and disputes in my group.*
- *I wish I could pick my team*

Other

- *Buy better glue! And electric drill and hammer.*
- *You should do this for high schools too—it was an awesome experience.*
- *More donuts, please!*

Summary: Fluid Power Challenge Ratings

Student mean ratings of the FPC were 4.1/5.0. Although there was a moderate though significant correlation between a student's rating and his or her interest in a fluid power career, nearly all students rated the FPC experience highly. Students overwhelmingly would recommend the FPC to any student they know (85%) for a variety of reasons, including it was fun, they enjoyed the teamwork, and it exposes them to career opportunities. Students provided thoughtful, open-ended reasons for recommending and not recommending FPC to others. Those who would not recommend often commented upon the level of difficulty and team dynamics. Level of difficulty might be addressed by considering ways to diversify challenges so that students who might not be academically prepared or inclined towards engineering can still benefit.

Team dynamics ought to be addressed expressly at the Workshop and Challenge days. Leadership and teambuilding are consistently listed at the top of engineering employer and college alumni surveys, and are the subject of much engineering research. Nowadays, teamwork is commonly implemented in middle schools. It seems natural that an experience designed to expose students to fluid power careers stakes out both the content knowledge as well as interpersonal skills that need to be developed in order to be successful, including teamwork skills. Several students' experience was enhanced or diminished by their team's dynamics. It would be highly appropriate to discuss teambuilding during the event, and include at least one question on the post-survey related to what students learned about working in a team.

Overall, the FPC was rated quite highly and the extent and nature of comments suggests it was highly valued by nearly all participants.

Fluid Power Concepts & Formulas

The pre- and post-surveys include several items that probe specific fluid power concepts and formulas. These items are quite test-like. QED assessed the proportion of correct and incorrect responses, based on NFPA-supplied answers. As per NFPA guidelines, QED was lenient in determining correct answers. If an expression was missing from a formula or a letter in the formula was wrong, we counted it as correct. In narrative answers, if words were missing or somewhat inaccurate, but the general point seemed on target, we counted it as correct. In answers with multiple possible correct responses, we gave broad latitude. The table below summarizes student responses.

The highest average letter grade equivalent students received as a group on a single item was B- for the item that asks students the two categories into which fluid power is categorized. All other items received D's or F's, meaning that the proportion of students who answered correctly was 60% or lower. The mean summed score for all items was 24, with a range of 10 (highest score) to 40 (lowest score). Two students received a score of 10 (100% on all items). The mean number of *No Respo*nses was 22.3%, with a range of 12.3% to 40.8%. This means that roughly one-quarter to one-third of students didn't answer several items. These data suggest that the concepts and formulas tested either are not taught or are not sufficiently reinforced through the FPC.

Summary of Post-Survey Items 8-17: Fluid Power Concepts							
	Item Scores						
Post-Survey Item	**100%**	**75%**	**50%**	**25%**	**0% or No Response**	***Mean % Correct***	***Letter Grade Equivalent***
7. FP is broken into what 2 major categories?	76.8*		6.3		16.9	*71%*	*B-*
8. List 4 advantages of FP	36.5	12.1	14.3	9.1	28.0	*50.5%*	*F*
9. Hydraulic power systems transfer power through what medium?	64.3				35.7	*60.7%*	*D*
10. Pneumatic power systems transfer power through what medium?	59.6				40.4	*58.1%*	*D-*
11. List 4 examples of a hydraulic fluid power system.	25.7	10.7	10.1	11.4	42.0	*37.5%*	*F*
12. List 4 examples of a pneumatic fluid power system.	17.6	6.0	6.0	14.2	56.3	*26.7%*	*F*
13. Viscosity measures …?	36.4				63.6	*33.7%*	*F*
14. Volume of a cylinder is measured by what formula?	45.2				54.8	*43.0%*	*F*
15. What is the formula to calculate pressure?	15.3				84.7%	*14.7%*	*F*
16. What is mechanical advantage?	4.4		15.1		80.4	*11.1%*	*F*

*Percent of students who received this score on this item.

Low scores on the post-survey concept items did not affect students' interest in fluid power, fluid power careers, or their ratings of the FPC. Correlations among these items are near zero, which is a positive finding.

Summary: Fluid Power Concepts & Formulas
The proportion of students who could answer items correctly related to fluid power concepts and formulas ranged from 4% to 77% per item, with a mean of 34%. Most students understood the two categories that fluid power is broken into. However, few could answer the other nine questions about fluid power applications, cite formulas, or provide definitions to key concepts. The modal response to six of the nine items was *0% Correct or No Response*.

QED wonders about the extent to which post-test items 7-16 align with the FPC goals? If the program is designed primarily to assess students' understanding of fluid power concepts, then the weight given to these items on the post-test is understandable. Yet, if depth of understanding is a goal, then results suggest that the goal is not being met. On the other hand, if the primary focus of FPC is to raise awareness of fluid power and fluid power careers, the heavy emphasis on concepts and formulas might be misplaced. Moreover, considering the profile of responses, it appears that students can succeed in the challenge without understanding the concepts tested. Again, this raises the question about the relevance and value of these survey items.

Conclusions
Students' survey responses suggest that the Fluid Power Challenge (FPC) is successful in its primary goals of heightening students' awareness of fluid power and fluid power careers, and sparking their interest in pursuing a career in fluid power. Surveys show dramatic shifts in students' self-reported knowledge of fluid power, moving from *Not At All/Minimally* at pre-survey to *Somewhat* and *Very* in the post-survey. There are also significant shifts related to their self-reported knowledge of fluid power careers, with responses shifting from *Not At All/Minimally* at the pre-survey to *Somewhat* in the post-survey. Students were split in the post-survey fairly evenly between those who are and who are not interested in a career in fluid power; however, comments suggest that several students were alerted to fluid power as a possible career.

Ratings of FPC were uniformly high, averaging 4.1/5.0 (1=Dull; 5=Exciting). The most often cited *best things about the FPC* was getting to build things and teamwork. Students found the FPC exciting, fun, and engaging. Eighty-five percent (85%) would recommend the FPC to "any student I know." Students provided thoughtful responses regarding why they would or would not recommend FPC. Whether students would recommend FPC to others was not based on their own interest in fluid power as a career.

Clearly, as an introductory experience to fluid power (and, for many, engineering), the experience is positive, engaging, and probably indelible. QED has conducted research that suggests a single school-related experience related to engineering can cause a student to want to study engineering after high school, even if that experience takes place in elementary or middle school. FPC is likely such an experience for some or many students.

Items related to fluid power concepts and formulas on both the pre- and post-survey serve questionable value. Conceivably, they could determine the efficacy of online lesson plans that NFPA offers in conjunction with FPC; however, surveys do not indicate whether students have had that or any other exposure. Therefore, results are not interpretable. These items on the post-survey are rarely answered correctly. Nor does answering them correctly seem to influence teams' success in the FPC.

The first item on the pre- and post-survey is *How familiar are you with fluid power?* QED asks NFPA what the organization/industry would want 8th graders to know about fluid power that might motivate them to explore it further in the immediate or long-term future? How specific must content knowledge about fluid power be in order for 8th graders to have the sense that they understand fluid power basics? Fluid power concepts currently found on the post-survey that are critical for success in the FPC should be covered at some length in the Workshop and reinforced at the Challenge. Overall, we urge NFPA to reflect on what *familiarity with fluid power* means in the specific context of FPC, and rethink the fluid power concepts and formula items on both the pre- and post-surveys.

The FPC seems to be successful in its primary goals to expose students' fluid power and fluid power careers, and spark interest in the field. On post-surveys, students report significantly increased familiarity with fluid power and with fluid power careers, and about half express an interest in pursuing fluid power professionally. QED's analysis suggests ways to strengthen this already-successful program in order to improve outcomes and support student's newfound interest in the fluid power industry.

Recommendations

1. The survey length is good. Students who started the survey tended to finish it. Many who stopped answering the concept and formula questions nevertheless provided a summary comment. Open-ended comments were thoughtful. Currently surveys are not matched by student pre vs. post. This is fine. Meaningful results can be obtained by a thoughtful cross-sectional analysis without inserting complicated logistics required to match pre- and post-surveys. The value of survey analysis will be enhanced if certain demographic items are included (see Recommendation #3).

2. If possible, arrange to administer the pre- and post-surveys online. Most schools now have the capacity to do this. Administering surveys online facilitates speedy summary of results, yielding insights about how to improve the program quickly. If NFPA moves to distribute the survey online, include protections against spamming, either by using a password or having students complete the survey on-site and deleting any surveys not completed on the day and time they were administered.

3. Consider adding at least one demographic item to the pre/post surveys having to do with gender. Other demographic items (e.g., familiarity with engineering, expected grade in math, desire to attend college) can provide information that would enable NFPA to better assess and address the needs of a range of students.

4. Ensure that each survey item aligns directly with the primary goals of the FPC. Expand on items related to interest and careers in fluid power. We recommend omitting most concept and formula items, except for those students must understand in order to be successful in the FPC or that NFPA determines are fundamental to a basic understanding of fluid power. Concepts and formulas included should be explicitly taught in the Workshop and reinforced on Challenge Day.

5. Extend response options on the item, *I am interested in a career in fluid power* to a 1-5 scale. Doing so will provide more information about the level of students' interest and yield valuable information when crossed with other items.

6. Add an item that assesses students' perceived efficacy in fluid power (e.g., *How confident are you that, with education and experience, you could succeed in a fluid power job or career?* 1=Not Confident, 2=A Little Confident, 3=Not Sure, 4=Moderately Confident, 5=Very Confident

7. Qualitative responses as well as existing research in this area, suggests that such an item could be a predictor of further study in fluid power. If the FPC enhances students' self-efficacy related to fluid power, that would be a significant "win" for NFPA.

8. Add an item to the post-survey about ways to improve the FPC. Such an item would balance *The best thing about FPC is...* Students' have provided thoughtful open-ended comments and may have excellent suggestions.

9. Incorporate a module into the FPC (or strengthen an existing one) about fluid power careers, either directly through instruction, or indirectly through online materials that can be accessed by teachers and students before, during, and/or after the event. Students who participate in FPC are excited about fluid power; can NFPA provide materials that scaffold that interest?

10. Incorporate into the FPC instruction, reflection, and/or assessment of the teamwork aspect of the experience. Teamwork is a critical engineering skill and essential for FPC success. Students' experiences with FPC are often shaped by a positive or negative team dynamic. Building instruction about teamwork into the process reinforces the importance of communication and leadership, and gives students a deeper understanding of engineering work.