Purdue University

Purdue e-Pubs

School of Engineering Education Faculty Publications

School of Engineering Education

7-2021

Exploring Young Women's Interest in Fluid Power with Workshop Experiences

Anne M. Lucietto
Purdue University, West Lafayette, IN, aluciett@purdue.edu

Jennifer D. Moss
Emporia State University

Jose M. Garcia
Purdue University

John H. Lumkes
Purdue University

2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32978

Exploring Young Women's Interest in Fluid Power with Workshop Experiences

Dr. Anne M. Lucietto, Purdue University

Dr. Lucietto has focused her research in engineering technology education and the understanding of engineering technology students. She teaches in an active learning style which engages and develops practical skills in the students. Currently she is exploring the performance and attributes of engineering technology students and using that knowledge to engage them in their studies.

Dr. Jennifer D. Moss, Emporia State University

Jennifer D. Moss, PhD, is an Assistant Professor of Psychology at Emporia State University in Emporia, Kansas. Her work is centered around educational psychology, examining motivation of students and teachers. She works primarily in self-determination theory, hoping to partner with instructors at all levels to create autonomy-supportive learning environments and promote instructor well-being. Dr. Moss has presented and published nationally and internationally. She teaches developmental and educational psychology courses for graduate and undergraduates.

Dr. Jose M. Garcia, Purdue University

Biography Dr. Jose Garcia has been involved in several local and statewide recruitment events, where he was able to develop short workshops in fluid power and STEM. He is also working on the development of a new generation of hydraulic components and systems that can operate using environmentally friendlier fluids. Dr. Garcia has plans to actively continue the development of practical teaching tools that bring industry applications to the classroom.

John H. Lumkes, Purdue University

John Lumkes is the Assistant Dean & Associate Director, Office of Academic Programs, in the College of Agriculture, and Professor of Agricultural and Biological Engineering at Purdue University. Dr. Lumkes received his Ph.D. from the University of Wisconsin in 1997. His current work focuses on agricultural automation and mechanization, international service-learning, fluid power, innovation and design, multi-domain modeling of dynamic systems, and mechatronics.

Exploring Young Women's Interest in Fluid Power with Workshop Experiences

Fluid power is not an engineering topic usually presented to students in grades K-12. However undergraduate students in various programs are required to learn this concept. Evidence exists that indicates college students are more easily engaged when fluid power has been introduced earlier in their schooling. Thus, a variety of organizations are beginning work toward providing programs to creatively present the topic to younger students. After an examination of existing literature, we found minimal evidence of this type of work having been carried out and reported on.

This study examines data from workshops designed to introduce fluid power to middle and high school students. These workshops introduced the use of fluid power components along with relevant theory. Students were queried after the workshop and after to assess interest/enjoyment, motivation, and interest in the workshop materials.

The results presented in this paper are useful for future workshop designers and presenters. We share specific information regarding student interest, timing, and type of materials that result in higher levels of interest along with the quality of presentation and demonstration materials. Also providing guidance on how gender makeup of groups during the workshop influenced these results. Further research opportunities are presented as well as suggestions on how to continue to increase interest, enjoyment, and value in fluid power as this may be applicable other areas of STEM.

Keywords: female, fluid power, middle school, high school, engagement

Background

Workforce positions involving science, technology, engineering, and math (STEM) are vital to the United States' economic well-being and our competitiveness in an international marketplace [1]. STEM workforce forecasts vary widely, from future shortages of over 1,000,000 STEM workers by 2026 [2] to current surpluses [3]. Regardless of shortages or surpluses, corporations and businesses may struggle to hire STEM workers with specific skill sets, such as designing and maintaining fluid power systems [4, 5].

According to the Center for Compact and Efficient Fluid Power (CCEFP) [6], fluid power is not frequently taught in K-12 schools, reducing, or eliminating a key method of exposure and interest-building for future workers. The CCEFP was founded as an NSF Engineering Research Center created specifically to bring together researchers, educators, and students from different universities to investigate fundamental and applied topics in fluid power. A CCEFP education and outreach committee was created with the intent to increase awareness of fluid power to diverse audiences in different age groups and populations by providing lesson plans and materials [6]. Likewise, the National Fluid Power Association (NFPA), adopted the fluid power educational foundation in 2017, and is now creating programs to reach out to various audiences, spawning from 6th grade to senior level in college.

Literature Review

Existing research has looked at instructional methods to increase interest in fluid power at the undergraduate level. Flipped classrooms, where content is reviewed before class and class time is spent on problem-solving activities, yielded positive student feedback as well as increased learning when compared to traditionally taught sections [7].

Raising Student Interest in Fluid Power

Blended classrooms, using extensive on-line tutorials and other materials available to students yielded positive results in learning and student satisfaction [8]. Team-based hands-on activities were implemented in another fluid power course and students reported that they felt their understanding and interest both increased due to the activities [9]. In yet another course, students completed interactive, competitive, and ungraded activities in class to enhance their learning of fluid power. Faculty involved in this course reported observing enhanced learning in this redesigned classroom climate [10]. These studies and others demonstrate that methods exist to increase learning and interest in fluid power at the undergraduate level [11].

Exposing students to fluid power and engaging students in related activities in middle school or high school is important to increasing the number of trained workers in later years, as students begin to choose career pathways during these years [12]. Additionally, having middle and high school students participate in real world, hands-on, engaging activities may be key to promoting interest in STEM careers [13].

Despite the importance of raising interest prior to undergraduate work, there is little existing literature on increasing interest in fluid power or fluid power in middle or high school students. The few references found discussed fluid power competitions at area high schools [14, 15] or described materials that could be built to demonstrate fluid power.

Women's Interest in STEM/Fluid Power

A great deal of research exists regarding ways to motivate and encourage female students to pursue technical careers in many areas of STEM [16-18]. Some of this research points out structural components that are beyond the scope of university researchers, such as gender of teachers and school-based ability grouping. Bottia, et al., [19] suggest that having female high school teachers in STEM disciplines encourages more women to pursue STEM fields in college, although it does not affect men in their participation in STEM. Wang and Degol [20] report that when students are separated into ability-tracked mathematics courses, girls can be overlooked due to lack of exposure to advanced material.

However, research on informal learning experiences has shown promise as another way to increase young women's interest in STEM fields. Informal learning is characterized as an activity that is typically selected by the participants, is often hands-on, and takes place in an informal setting that is occasionally, but not frequently, visited such as a museum, a planetarium, or a university [21]. Dabney, Johnson, Sonnert, and Sadler [22] discovered that informal science experiences during high school predicted the choice of a STEM major by undergraduate women. Kim, Sinatra, and Seyranian [23] also identified informal experiences, including mentoring by female researchers, as a factor in adolescent women's STEM interest.

An additional aspect of informal learning that researchers have discussed is whether female students' STEM identity formation, another factor related to interest [24] is influenced by the gender composition of groups during activities. When middle-school participants from an all-female STEM camp were compared with those in a mixed-gender STEM camp, gender played no role in the young women's STEM identity formation [25]. Researchers found similar results when measuring interest across three mixed-gender informal STEM learning groups and one all-female group of adolescent students [26]. While historically, males have been more likely to indicate interest in STEM [27], the gender of the STEM informal learning groups appears to not significantly influence female students' interest.

In our review of the literature, examining informal learning, gender, interest, and value in STEM, it was determined that existing work involves many different interventions and modes of study (e.g., [22, 28-31]. However, we were unable to find any exclusively focused on fluid power.

Intrinsic Motivation, Interest, and Value

Self-determination theory [32] posits that motivation can be described as a spectrum. At the lowest end is amotivation, or a complete lack of motivation. External regulation, motivation based upon gaining rewards and avoiding punishments is next. Slightly more internal is introjected regulation, where tasks are performed to avoid shame and guilt. Identified regulation is when tasks are completed for the importance. Integrated regulation is the term for when activities are undertaken because they are valued, and at the highest end of the spectrum is intrinsic motivation, where one engages in a task for the internal sense of enjoyment [32]. Intrinsic motivation also promotes classroom engagement, and engagement is typically preceded by student interest [33-35].

Research Questions

Having identified a gap in the literature regarding adolescents, gender, intrinsic interest, and value in fluid power, we set about examining data on that had been collected as part of informal fluid power workshops delivered to middle and high school students. The purpose of our research is to assess the level of interest and value students report after completing the workshop, focusing on the female students.

As we previously stated, we were not able to find any interventions assessing adolescents' interest or value in fluid power. We consider our analyses to be exploratory in nature and hope to create a base on which future work can be built. Therefore, we are not putting forth hypotheses. Instead, we have identified three research questions.

- *First, what level of interest and value do students report after completing an informal fluid power workshop?*
- *Second, are the interest and value reported by male students different from those reported by female students?*
- *Third, does the gender composition of the group play a part in the reported interest and value by female students?*

Methods

This research is defined through the following areas: participants, workshops, and measures. Each if these are defined in the following sections.

Participants

The data that we are examining come from informal fluid power workshops for middle and high school students held during 2009 and 2010. There was a total of 18 groups for which we had survey data, and the groups ranged in size from 4 students to 48 students, with a mean of 17 students and a standard deviation of 5. Participating students attended workshops on a university campus which were sponsored by of a variety of organizations designed to educate students on STEM opportunities, including the YMCA, Women in Engineering Programs (WEIP), Minorities in Agriculture, Natural Resources, and Related Sciences (MANNRS), and others.

Including all the workshops, there were 625 participants, including data collected from adult chaperones who attended with the students. We restricted our sample to participants for which we had survey data and to participants who were age 19 or under, indicating that they were of the age to have been in or just finished high school. Survey data was collected for 441 students. We then restricted our sample to only students who reported both age and gender. This left a sample of 415 students. Of those students, 223 were female and 192 were male. Ages ranged from 11 to 19 with a mean age of 15.7 and standard deviation 1.66. Over half of the participants were between 16 to 19 years of age.

Workshops

Hands-on workshops were designed with the CCEFP education and outreach committee's goals of providing more outreach in fluid power for more audiences. The workshops typically lasted approximately 30 to 45 minutes. During the workshops, presenters gave a short introduction on fluid power along with the functions of basic components in a fluid power system. They were introduced to the micro-excavator which is fluid powered and shown how the different parts contribute to the whole [36]. Then the students, in groups of approximately 4 to 5, were then given a schematic of the micro-excavator along with the necessary components to build and operate it. Most groups of students were able to assemble the micro-excavator without difficulty. When complete, students were tasked with operating the arm and were allowed use the micro-excavator to dig in the sand table upon which they had built the excavator [37].

Measures

At the conclusion of the workshop, students completed a 14-question survey with two additional open-ended questions, and provided demographic information. The survey questions (see Appendix A) were selected and some were modified from the interest/enjoyment and value subscales of the Intrinsic Motivation Inventory (IMI) [38]. It is worth noting that the IMI is a post-experimental survey, designed to assess interest once an event or an experimental manipulation is complete. Having used it in this way, we do not have data which shows what the student interest was before they interacted with the micro-excavator.

Of the original fourteen questions from the two IMI subscales, six questions from each subscale were retained. Nine were retained in their original form. Three IMI questions were modified to include language addressing the specific experiment and science/math in general. Over the history of the IMI, researchers have frequently modified questions in order to focus questions on a topic or experience (e.g., [39, 40]). In addition to the 12 IMI questions, two new questions were added to provide feedback about the workshops, asking if participants thought the material was difficult to grasp and if they would recommend an activity like the workshop be presented at their school. The overall Cronbach's alpha reliability [41] for the survey is .89 which would be considered to be very good. The six-question interest/enjoyment subscale had a reliability of .77 which is considered good and the six-question value subscale had a reliability of .81, which would also be considered good. These reliability numbers are in line with other uses of the IMI [39, 40].

The students were asked to report on their most favorite aspect of the micro-excavator activity and their least favorite aspect. These questions, like the two survey questions that were not drawn from the IMI, were included to solicit participant feedback and help the researchers continue to make improvements. All survey and open-ended questions were collected to improve the existing program. The data were stripped of any identifying student-level information before analyses began.

Results/Findings

Our first research question asked what level of interest and value do students report after completing an informal fluid power workshop. It is important to note that the Intrinsic Motivation Inventory (IMI), the measure that was used in our study to assess interest, is not intended for pre- and post-administration [38] so we do not have a measure of interest before the workshops began. The IMI is assessed on a 7-point Likert-type scale giving it a midpoint of 4. If a mean of student responses surpassed 4, that showed it indicated interest or value, and below four, it was showing a lack of interest or value. On the Interest/Enjoyment subscale, the overall mean was 6.09, which indicated that students expressed interest in the workshop. On the Value subscale, the overall mean was 5.28, which indicated that students found value in the workshop, as shown in Table 1.

IMI Dimension	N	Low	High	Mean	SD
Interest/Enjoyment	415	3.00	7.00	6.09	.83
Value	415	1.00	7.00	5.28	1.18

Table 1. *Mean IMI Scores of All Students*

Our second research question asked if there would be a difference in the responses of female and male students. When we analyzed the responses by gender, we found that males reported significantly more interest/enjoyment and value than female students did. On the Interest/Enjoyment subscale, the mean for females was 5.88 and the mean for males was 6.33. On the Value subscale, the mean for females was 5.03 and the mean for males was 5.59. We conducted an independent samples *t*-test and discovered that the differences between the female and male students on interest/enjoyment and value were both statistically significant. The *t* test for interest and enjoyment, $t(413) = -5.67$, $p < .001$, showed that male students reported significantly more interest and enjoyment, and the difference between the means of .45 scale points indicated a moderate effect of gender, $d = .55$. The *t* test for value, t (413) = -4.862, p < .001, showed that the male students reported significantly more value, and the difference between the means of .56 scale points indicated again a moderate effect of gender, d = .50, as shown in Table 2 below.

	Females (n=223)		Males (n=192)		*t*(413)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Interest/Enjoyment	5.88	.90	6.33	.67	5.67	.000	0.55
Value	5.03	1.25	5.59	1.03	4.86	.000	0.50

Table 2. *Independent t-Tests for Interest/Enjoyment and Value Between Males and Females*

Our third question asked if there would be a difference in interest and enjoyment or value reported by female students, depending on the gender composition of the workshop. For ease in analysis and interpretation, the groups were divided into three groups, depending on the percentage of female students: 9 – 49% (6 groups), 50 – 75% (7 groups), and 100% (5 groups). While these clusters are not divided into strict tertials, this method allowed for similar numbers of groups within each cluster while also allowing us to analyze groups that were less-than-half female, more-than-half female, and all female. There were no groups with all male participants, and there were no groups with 76 to 99% females.

To answer the question about the effect of group gender composition, we first selected only the female students in the data set. We then correlated their responses on the Interest/Enjoyment and

Value subscales by the percentage of females in their workshop group. In the case of Interest/Enjoyment, there was no relationship with the percentage of females, $r = .02$, *ns*. However, when we examined Value and percentage of females, we found a significant relationship, indicating that as the percentage of females increased the value that they reported at the end of the workshop also increased, $r = .11$, $p < .05$.

To address any confounding variables, we also investigated the relationship of age among the female students. Age was correlated with Interest/Enjoyment, $r = .21$, $p < .01$, indicating that as age increased, reported interest and enjoyment of the workshop increased. Age was also correlated with Value, $r = .24$, $p < .01$, indicating that as age increased, reported value in the workshop increased. Age was also correlated with the percentage of females in the workshop group, $r = .18$, $p < .01$, demonstrating that the more females were in the group, the more likely they were to be older female students. While this was not part of our research question, it is not completely unexpected as some of the workshop sponsor groups, such as Women in Engineering, were designed to attract young women who are exploring college majors, and therefore likely older than the youngest participants who were in junior high as shown in Table 3 below.

Variable	*n*	*M*	*SD*	1	2	3
1. Age	223	15.6	1.62	—		
2. Interest/ Enjoyment	223	5.88	0.90	$.214^{**}$	—	
3. Value	223	5.03	0.27	$.244^{**}$	$.729^{**}$	—
4. Percent of Females	—	—	—	$.179^{**}$	.019	$.144^{*}$

Table 3. *Correlation Among Female Participants' Age and Their Interest/Enjoyment and Value for Workshops*

Since age and percentage of females in the workshop group were both correlated with reported value, we ran a multiple linear regression to determine where the effect was situated. The results of the regression indicated that the two predictors explained 5% of the variance, ($R^2 = .05$, $F(2, 220) = 5.33$, $p < .001$). However, deconstructing the results of the multiple regression showed that all the variance came from age as a predictor. It was found that only age significantly predicted value, ($\beta = .22$, $p < .01$), and percentage of females did not significantly predict value when age was accounted for ($\beta = .02$, *ns*).

Once we had discovered that age predicted reporting value in the workshops for female students, and was correlated with interest/enjoyment in the workshops, we wanted to explore other potential relationships with age of female participants. There were two additional questions that were added to the IMI in order to provide feedback to the workshop creators: one addressing difficulty, and another asking if the student would recommend a workshop like this be held at their school. Among female participants, age was not related to the interest in having a workshop at their school. However, age was significantly negatively related to whether the female students felt the workshop material was difficult to understand, $r = -.21$, $p < .01$, meaning that the older the female student was, the less likely she was to indicate that she found it difficult to grasp new concepts taught during the workshop. Among male participants, age was not correlated with perception of difficulty, interest in having a workshop at their school, Interest/Enjoyment, or Value.

Discussion

In our analyses of the results of the modified IMI survey given to participants of the fluid power workshops, we found support for two of our three research questions. First, we found that after the workshop, students were interested and found value in the activity. The Likert-type scale is labeled Not/Some/Very as a guide for the students in choosing their ratings of the activity, so ratings of 6.1 out of 7 in interest/enjoyment and a rating of 5.3 out of 7 in value demonstrate that students did find interest/enjoyment and value. In the terms of self-determination theory, at the end of the event students showed intrinsic motivation, through interest and enjoyment, for the fluid power activities. They reported some degree of integrated regulation, reporting internalized value for workshop as well.

In answering our next research question regarding the potential difference in reported interest and value among participants, we found that female students reported less overall interest/enjoyment and less overall value than male students did. Comparing the mean levels to the IMI scale, we can see female students reported a mean level of 5.9 of 7 in interest/enjoyment and a mean level of 5.0 of 7 in value. Even though the scores of the female students were lower than the males at a statistically significant level, we feel that this is positive news because the scores of the young women still indicated they found intrinsic motivation and integrated regulation for the workshops.

Our final research question asked if the percentage of females in the workshop group would have an impact on the female students' reported interest/enjoyment or value. There was no effect of percentage of females in the group for interest/enjoyment. However, we discovered that while there appeared to be different levels of value reported based on the percentage of females in the workshop groups, this difference was an effect of age. The older female students tended to be in the all-female groups hosted by groups targeting STEM interest for future college students. These young women might have reported increased value as they are close to enrolling in college and found a workshop on fluid power valuable as they narrow down their potential interests.

When examining the relationship of age and the other variables of interest, we discovered that as female students grew older, they were more likely to report interest in the workshop, as well as less likely to report difficulty in understanding the workshop material. These differences were not seen among the male students where there was no relationship between age and interest/enjoyment, value, or perception of difficulty.

Another interesting discovery was that regarding interest in having a workshop similar to the one that they had participated, female students' response was positively correlated with their interest/enjoyment and their perception of value, but negatively correlated with the level of difficulty that they perceived in the workshop material. Male students' interest in having a similar workshop at their school was only correlated with their interest/enjoyment and perception of value but not with their sense of difficulty. Unlike male students, female students' interest in further workshops depended upon how difficult they thought the workshop was.

Overall, these analyses raise three key points. First, female students' interest is likely not affected by the gender composition of the workshop group, in line with previous research [25, 26]. Second, young women appear to perceive more interest/enjoyment and value in workshops like this when they are older, as opposed to across their school years, as it appears for young men. Third, young women may also perceive more interest/enjoyment and value when they also perceived that the material is accessible, again unlike the young men in our sample whose interest did not vary as a factor of their perceived difficulty understanding the material.

Implications and Future Directions

Our findings raise important issues that researchers and STEM workshop presenters may find useful. When considering how to interest young women in STEM fields, it may be likely that their interest is higher as they approach the end of high school and begin to consider potential jobs and college majors. Workshops that are designed to appeal to female students before their junior or senior year of high school may need to be designed differently to capture their interest. In addition, it may be useful in future workshops to make sure that all students, but especially young women, find the material accessible because their interest, enjoyment, and value depend upon how well they feel that they understand the new concepts.

While it may be difficult to generalize beyond our sample, moving forward, researchers may want to investigate why the questions surrounding the timing and accessibility questions regarding young women's interest in and perceived value of STEM workshops. Were these issues solely related to fluid power or are they seen in other areas of STEM? Since we found that perceived difficulty of the material decreased as the young women got older and interest and value increased as the young women got older, how do we facilitate competence, intrinsic motivation, and internalization among younger female students?

Limitations

There two key limitations that we acknowledge in our analyses. First, the participating students were not randomly selected. They attended the fluid power workshops because they were part of a group which was scheduled to attend, such as a YMCA summer camp, or they were attending as a student who was exploring a potential interest for future college studies, such as the young women attending through the Women in Engineering program.

Second, we also acknowledge that the measure used to assess outcomes was not designed to be a pre/post instrument. This removed the potential for us to conduct analyses of students' prior interest or value in fluid power. We were only able to assess the variables of interest after the workshop was completed. Future research on the fluid power workshops should include an assessment that can be reliably administered before and after the workshop. This would provide the opportunity to see if students' interest/enjoyment or their value grew over the course of the workshop.

Conclusion

Our work with over 400 students from 18 groups in our pilot study has shown us that after a hands-on workshop, students do report interest, enjoyment, and value in fluid power, achieving the goal of the CCEFP education outreach committee of bringing fluid power to a wider audience. Events and activities such as this could may be a way to increase knowledge of fluid power as well as highlight areas where there may be STEM workers shortages in the future.

We did not see that the young women were affected by the gender composition of the group. However, since the older female participants expressed more interest and value toward the end of high school, future programs may want to capitalize on this and provide programs targeting young women at that time. Workshops delivered in the last two years of high school may increase intrinsic motivation and integrated regulation for fluid power in young women at a time when they are considering college majors and future career paths.

References

[1] National Center for Education Statistics. "Nontraditional Undergraduates/Definitions and Data/Who is Nontraditional?" National Center for Education Statistics. http://nces.ed.gov/pubs/web/97578e.asp (accessed 2015).

[2] R. Iammartino, J. Bischoff, C. Willy, and P. Shapiro, "Emergence in the US Science, Technology, Engineering, and Mathematics (STEM) workforce: an agent-based model of worker attrition and group size in high-density STEM organizations," *Complex & Intelligent Systems,* vol. 2, no. 1, pp. 23-34, 2016.

[3] Y. Xue and R. C. Larson, "STEM crisis or STEM surplus? Yes and yes," *Monthly labor review,* vol. 2015, 2015.

[4] P. J. Denning and E. E. Gordon, "A technician shortage," *Communications of the ACM,* vol. 58, no. 3, pp. 28-30, 2015.

[5] National Science Board, "NSB-2018-7. A Policy Companion Statement to Science and Engineering Indicators 2018," 2018. [Online]. Available: nsf.gov/statistics/indicators

[6] Center for Compact and Efficient Fluid Power. www.ccefp.org/education/teaching-and-learning-resources/ (accessed January 14, 2021).

[7] D. R. Webster, D. M. Majerich, and A. G. Madden, "Flippin'Fluid Mechanics--Comparison Using Two Groups," *Advances in Engineering Education,* vol. 5, no. 3, p. n3, 2016.
[8] S. Rahman, "A Vision for Our Society: Make PES More Relevant to Working Professionals [Leader's Corner]," *IEEE Power and Energy Magazine,* vol. 14, no. 2, pp. 6-6, 2016.
[9] T. Wei and J. Ford, "Enhancing the connection to undergraduate engineering students: A hands-on and team-based approach to fluid mechanics," *Journal of STEM Education: Innovations and Research,* vol. 16, no. 2, 2015.
[10] R. W. M. Pott, K. E. Wolff, and N. J. Goosen, "Using an informal competitive practical to stimulate links between the theoretical and practical in fluid mechanics: A case study in non-assessment driven learning approaches," *Education for Chemical Engineers,* vol. 21, pp. 1-10, 2017.
[11] E. D. Bonnett, "The Use of Sustained Experience in 4-H Fluid Power Education to Influence STEM Perception in Middle School Youth," Purdue University Graduate School, 2019.
[12] E. Torpey, "Clusters, pathways, and BLS: Connecting career information," *Bureau of Labor Statistics,* 2015.
[13] R. Christensen, G. Knezek, and T. Tyler-Wood, "Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students," *Journal of Science Education and Technology,* vol. 24, no. 6, pp. 898-909, 2015.
[14] Anonymous, "NFPA Fluid Power Challenge engages students," (in English), *Hydraulics & Pneumatics,* vol. 61, no. 6, pp. 11-12, Jun 2008 2014-05-23 2008. [Online]. Available: https://www.proquest.com/trade-journals/nfpa-fluid-power-challenge-engages-students/docview/213792629/se-2?accountid=13360
[15] L. Scully, "NFPA Announces Winner of the FIRST Robotics Scholarship," (in English), *Hydraulics & Pneumatics,* 2017 Aug 03 2017-08-04 2017. [Online]. Available: https://www.proquest.com/trade-journals/nfpa-announces-winner-first-robotics-scholarship/docview/1925790193/se-2?accountid=13360
[16] D. N. Beede, T. A. Julian, D. Langdon, G. McKittrick, B. Khan, and M. E. Doms, "Women in STEM: A gender gap to innovation," *Economics and Statistics Administration Issue Brief,* no. 04-11, 2011.
[17] M. L. Davison, G. B. Jew, and E. C. Davenport, "Patterns of SAT Scores, Choice of STEM Major, and Gender," *Measurement and Evaluation in Counseling and Development,* vol. 47, no. 2, pp. 118-126, 2014.
[18] J. S. Eccles and M.-T. Wang, "What motivates females and males to pursue careers in mathematics and science?," *International Journal of Behavioral Development,* p. 0165025415616201, 2015.
[19] M. C. Bottia, E. Stearns, R. A. Mickelson, S. Moller, and L. Valentino, "Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM," *Economics of Education Review,* vol. 45, pp. 14-27, 2015.
[20] M.-T. Wang and J. Degol, "Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields," *Developmental Review,* vol. 33, no. 4, pp. 304-340, 12// 2013, doi: http://dx.doi.org/10.1016/j.dr.2013.08.001.

[21] H. Esach, "Bridging In-school and Out-of-school Learning: Formal," *Non-Formal, and Informal Education. Journal of Science Education and Technology,* vol. 16, no. 2, 2007.
[22] K. P. Dabney, T. N. Johnson, G. Sonnert, and P. M. Sadler, "STEM career interest in women and informal science," *Journal of Women and Minorities in Science and Engineering,* vol. 23, no. 3, 2017.
[23] A. Y. Kim, G. M. Sinatra, and V. Seyranian, "Developing a STEM identity among young women: a social identity perspective," *Review of Educational Research,* vol. 88, no. 4, pp. 589-625, 2018.
[24] M. Pellerone, A. Passanisi, and M. F. P. Bellomo, "Identity development, intelligence structure, and interests: a cross-sectional study in a group of Italian adolescents during the decision-making process," *Psychology Research and Behavior Management,* vol. 8, p. 239, 2015.
[25] R. M. Hughes, B. Nzekwe, and K. J. Molyneaux, "The single sex debate for girls in science: A comparison between two informal science programs on middle school students' STEM identity formation," *Research in Science Education,* vol. 43, no. 5, pp. 1979-2007, 2013.
[26] S. Sontgerath and R. N. Meadows, "A Comparison of Changes in Science Interest and Identity and 21st Century Learning Skills in a Mixed-Gender and Single-Gender Robotics Program for Elementary/Middle School Youth," in *2018 CoNECD-The Collaborative Network for Engineering and Computing Diversity Conference*, 2018.
[27] M. G. Jones, A. Howe, and M. J. Rua, "Gender differences in students' experiences, interests, and attitudes toward science and scientists," *Science education,* vol. 84, no. 2, pp. 180-192, 2000.
[28] M. E. Cardella, "Informal pathways to engineering: preliminary findings," *age,* vol. 24, p. 1, 2014.
[29] A. M. Cox, "Space and embodiment in informal learning," *Higher Education,* vol. 75, no. 6, pp. 1077-1090, 2018.
[30] S. Jeong, S. J. Han, J. Lee, S. Sunalai, and S. W. Yoon, "Integrative literature review on informal learning: antecedents, conceptualizations, and future directions," *Human Resource Development Review,* vol. 17, no. 2, pp. 128-152, 2018.
[31] B. L. Todd and K. Zvoch, "The effect of an informal science intervention on middle school girls' science affinities," *International Journal of Science Education,* vol. 41, no. 1, pp. 102-122, 2019.
[32] R. M. Ryan and E. L. Deci, *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications, 2017.
[33] M. Ainley, "Students' interest and engagement in classroom activities," in *Handbook of research on student engagement*: Springer, 2012, pp. 283-302.
[34] J. M. Froiland and F. C. Worrell, "Intrinsic motivation, learning goals, engagement, and achievement in a diverse high school," *Psychology in the Schools,* vol. 53, no. 3, pp. 321-336, 2016.
[35] Z. W. Goldman, A. K. Goodboy, and K. Weber, "College students' psychological needs and intrinsic motivation to learn: An examination of self-determination theory," *Communication Quarterly,* vol. 65, no. 2, pp. 167-191, 2017.
[36] L. A. Mishler, J. M. Garcia, and J. H. Lumkes, "Engaging Pre-College Students in Engineering Using Hands-on Micro-Processor Controlled Portable Fluid Power

Demonstrators," in *2011 Louisville, Kentucky, August 7-10, 2011*, 2011: American Society of Agricultural and Biological Engineers, p. 1.

[37] J. M. Garcia, Y. A. Kuleshov, and J. H. Lumkes, "Using fluid power workshops to increase STEM interest in K-12 students," presented at the 121st ASEE Annual Conference, Indianapolis, IN, 2014.

[38] E. McAuley, T. Duncan, and V. V. Tammen, "Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis," *Research quarterly for exercise and sport,* vol. 60, no. 1, pp. 48-58, 1989.

[39] M. Gutiérrez, L.-M. Ruiz, and E. López, "Perceptions of motivational climate and teachers' strategies to sustain discipline as predictors of intrinsic motivation in physical education," *The Spanish journal of psychology,* vol. 13, no. 2, pp. 597-608, 2010.

[40] K.-C. Yeh, "Using an educational computer game as a motivational tool for supplemental instruction delivery for novice programmers in learning computer programming," in *Society for Information Technology & Teacher Education International Conference*, 2009: Association for the Advancement of Computing in Education (AACE), pp. 1611-1616.

[41] D. G. Bonett and T. A. Wright, "Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning," *Journal of Organizational Behavior,* vol. 36, no. 1, pp. 3-15, 2015.