

## **A Systematized Review: Gender and Race in Teamwork in Undergraduate Engineering Classrooms**

**Mr. Behzad Beigpourian, Purdue University, West Lafayette**

Behzad Beigpourian is a Ph.D. student and Research Assistant in Engineering Education at Purdue University. He earned his master's in Structural Engineering from Shahid Chamran University in Iran, and his bachelor's in Civil Technical Teacher from Shahid Rajaei Teacher Training University in Iran, Tehran. He has been official Technical Teacher at Ministry of Education in Iran from 2007 to 2018, and received many certificate in education such as Educational Planning, Developing Research Report, and Understanding School Culture. During these years, he has taught construction courses in several technical schools. Mr. Beigpourian currently works in the CATME project, which is NSF funding project, on optimizing teamwork skills and assessing the quality of Peer Evaluations.

**Dr. Matthew W. Ohland, Purdue University-Main Campus, West Lafayette (College of Engineering)**

Matthew W. Ohland is Professor of Engineering Education at Purdue University. He has degrees from Swarthmore College, Rensselaer Polytechnic Institute, and the University of Florida. His research on the longitudinal study of engineering students, team assignment, peer evaluation, and active and collaborative teaching methods has been supported by the National Science Foundation and the Sloan Foundation and his team received Best Paper awards from the Journal of Engineering Education in 2008 and 2011 and from the IEEE Transactions on Education in 2011 and 2015. Dr. Ohland is an ABET Program Evaluator for ASEE. He was the 2002–2006 President of Tau Beta Pi and is a Fellow of the ASEE, IEEE, and AAAS.

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## **Abstract**

Teamwork is an essential skill for undergraduate engineering students, and engineering instructors often form teams in the classrooms. However, many factors can affect the effectiveness of teamwork. One factor that could affect the result of teaming is the diversity in teams. Although team diversity could increase creativity and innovation in teams, if not managed well, it could also have negative consequences for teams. Of the various forms of diversity, race and gender have received the most attention in the literature, likely because they provide visual cues to teammates. In this study, we conducted a systematized literature review related to the race and gender in teamwork. To do this systematized literature review we followed the procedure suggested by Borrego, Foster, and Froyd [1]. We searched four different databases including Compendex, Scopus, ERIC, and Education Source. We found 224 articles and used 18 articles for this systematized literature review. We found women and minorities can be affected by working in teams by the perception of professors and students, mode of collaboration and communication, leadership style, team formation strategies, and peer evaluation. We also suggested how we can increase the effectiveness of teamwork in diverse teams.

## **Introduction**

With the goal of improving the conditions for diversity in engineering, engineering education researchers have investigated race and gender issues in the undergraduate years. Mcloughlin [2] studied the gender bias in undergraduate engineering. Amelink and Creamer [3] investigated that how much gender affected the satisfaction about studying engineering and how much this satisfaction influenced students' choice for working as an engineer in the future. Ohland et al. [4] compared two success measurements (eight-semester persistent and six-year graduation rate) of engineering students in different institutions based on different race and gender. Pawley, Schimpf, and Nelson [5] analyzed the content of papers that published in the journal of engineering education from 1998 to 2012 to understand how much these papers connected gender theories to engineering education. Even without considering the results from these studies, we can see authors exploring various issues related to race and gender in the undergraduate years.

However, teamwork is of particular interest in this discussion because it presents opportunities for engaging with other students in interdependent activity. Research on teamwork in engineering education has focused on both team formation [6] and peer evaluation [7], [8]. Also, there are many other papers that investigated different factors in teamwork. For example, Asio, Cross, and Ekwaro-Osire [9] studied factors such as leadership, conflict, communication and effort that can influence innovation in engineering student design teams. Engineers should expect to work professionally in diverse teams, and the effect of diversity has also been studied in professional teams. Using age and gender

diversity mixed teams can result in sustaining productivity in manufacturing [10], and cultural diversity can influence the performance of global teams in the innovation process [11]. So, universities need to prepare students for that experience. In this research, we found papers related to race and gender in undergraduate engineering teams. We did not include other types of diversity like language in this paper to focus more on results related to race and gender. Our goal is to guide engineering instructors about any possible issue related the race and gender in teamwork. Also, we summarize some suggestions that instructors can use to reduce the negative impact of race and gender diversity.

### **Scope and research questions**

In this systematized literature review, we focused on literature that is related to undergraduate engineering student teams, that provided any information that might help instructors in forming or managing teams, and that addressed issues of race or gender.

Research question: What factors related to the experience of women and minorities while working on a team has been investigated by engineering education authors?

### **Methods**

For this paper, the method we chose is systematized literature review. Systemized literature review is a method in education and other fields to critically analyze other research papers in a specific area [1]. In this method, we started with finding search strings related to the race and gender in teams, then selected appropriate databases for our research. By finalizing the best possible search indexes and keywords, we reviewed the papers identified more thoroughly. Below, we described each stage in detail:

### **Search Indexes**

We searched four different databases for this paper. Since we conducted our study for only undergraduate engineering classrooms, we decided to choose Compendex because this database includes many papers in engineering. Then, we selected the Scopus because it has many peer-reviewed journals, and finally we added ERIC and Education Source databases to include papers that are in education.

### **Keywords and Search Procedure**

There are many keywords which we could use in our paper like “team”, “collaboration”, “minorities”, and “women”. After testing different keywords and different combinations of them, we found the best research strings for each database. Below, in table 1, we provided the final research strings as well as the date of research and number of articles.

Table 1. Search strings for databases used

Database	Research strings	Date of search	Number of articles
Compendex	((((team* OR collaborat*) WN TI) AND ((minorit* OR wom?n OR diversity OR underrep* OR gender OR race) WN KY)) AND ((engineer*) WN KY)) + ({united states} WN CO) AND ({ja} WN DT) AND ({english} WN LA)	09/30/2018	72
Scopus	(TITLE(team* or collaborat*) AND TITLE-ABS-KEY(minorit* OR wom?n OR diversity OR underrep* OR gender OR race)AND TITLE-ABS-KEY(engineer*)) AND ( LIMIT-TO ( AFFILCOUNTRY,"United States" ) ) AND ( LIMIT-TO ( DOCTYPE,"ar" ) ) AND ( LIMIT-TO ( LANGUAGE,"English" ) ) AND ( LIMIT-TO ( SRCTYPE,"j" ) )	09/30/2018	71
ERIC	TI ( team* OR collaborat* ) AND TX ( (minorit* OR wom?n OR diversity OR underrep* OR gender OR race ) AND TX engineer*	09/30/2018	38
Education Source	TI ( team* OR collaborat* ) AND AB ( (minorit* OR wom?n OR diversity OR underrep* OR gender OR race ) AND AB engineer*	09/30/2018	43

We searched “team” and “collaboration” strings in the title to find articles that are more focused on the team. Then, we searched other keywords in the abstract to find more results.

### **Inclusion and Exclusion Criteria**

We narrowed our search to peer-reviewed journals to find the most credible research. We included only papers in English which collected the data from U.S. institutions because we wanted to find results that were most relevant to students in U.S. universities.

### **Selection Process**

By searching the strings provided in table 1, we found 224 articles and subsequently removed duplicates that occurred in the search process. Then, we read the articles at the title and abstract level, and 170 articles did not meet our criteria for inclusion. After reading the full text for remaining 40 articles, we removed another 22 articles. Finally, we kept 18 articles for review in this study. Figure 1 illustrates the selection process.

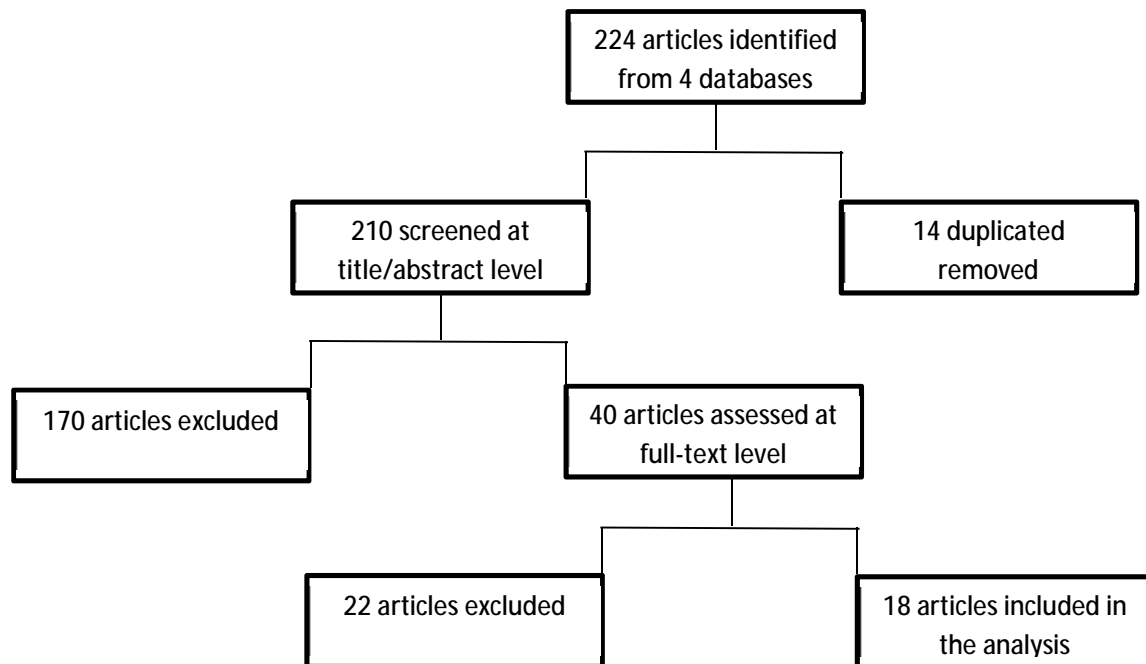


Figure 1. Adaptation of the PRISMA flowchart for described search process [12]

## Results

We analyzed the remaining 18 articles that investigated race and gender in engineering teamwork at U.S. institutions. Two of these articles studied race [13], [14], and ten papers were related to gender [15]–[24]. Another six papers investigated both race and gender [25]–[30]. For better understanding papers’ results, we categorized them and each different category describing one facet of teamwork covered by papers: collaboration, communication, leadership and self-efficacy, peer evaluation, perceptions of professors and students, team effectiveness and outcome, and team formation. We extracted any result related to the race and gender and ignored other results of papers.

### Collaboration

Three papers were about the mode of collaboration [20], [21], [23]. Flynn et al. [20] investigated the effect of mode of collaboration on female students while working in teams. The authors studied two different engineering teams working on the capstone project. One team consisted of two men and two women. The mode of collaboration in this team was dialogic. Another team consisted of two women and three men and the mode of collaboration had the characteristics of dialogic, asymmetrical and hierarchical modes. In the first team, female students were treated equally with men and there was no major conflict among team members. But, in the second team, female students were often ignored, and the team was dominated by men.

In the second paper, Berenson et al. [21] investigated the impression of female students in software engineering about doing projects as a team instead of working alone. These students

used pair-programming and solo group modes of collaboration on projects in this class. In this study, the authors interviewed with three female students to understand their opinions about collaborating in teams. According to this paper, all three females had positive views about this collaboration. Face-to-face meeting increased the satisfaction among female students, collaboration increased the quality of females' work, increased their confidence, and they became more interested to work on career related to their study.

In addition to these two papers, Stump et al. [23] studied the difference between women and men in course grade, self-efficacy, and self-reporting collaboration score. Although there was not any statistically significant difference for course grade and self-efficacy, women's engagement in collaboration for learning was significantly higher than men's with the average self-reported collaboration of 3.45 against 3.12.

### **Communication**

One paper had a result related to communication: Wolfe and Powell [17] studied the perception of engineering men and women through their typical speech patterns. They used six different transcripts extracted from actual conversions in teams. Half of the transcripts used feminine speech patterns and half used masculine speech patterns. Then, they randomly distributed these transcripts among first-year engineering students as well as students in other disciplines. They found that men in engineering were harsher than other groups in evaluating feminine speech patterns. For example, in feminine speech style, in which the speaker admitted her mistake, men in engineering saw these speakers as incapable students who were not able to do a good work. On a positive note, this bias was only related to the style of speech and the gender of speaker did not affect the result because each transcript.

### **Leadership self-efficacy**

Five papers addressed leadership role [18], [19], [27], [29], [30]. Although the primary focus of Rosch and Collier [29] was the difference between engineering students enrolled in the leadership theory course and engineering students enrolled in a team-based project course in term of leadership self-efficacy and motivation to lead, this study identified results related to gender in engineering student teams. They found that female students had 6 percent to 11 percent higher motivation compared to male students to lead teams and equal degrees of leadership self-efficacy with male students. They found no significant difference by race.

Rosch et al. [18] studied the difference between the students' perceptions of their leadership competency with their teammate's perceptions of their leadership competency, as well as the effect of gender on these perceptions. The authors found that the scores males gave to females was higher than the scores female given to males. However, the biggest difference was between scores females gave themselves and their ratings by males.

Rowan-Kenyon et al. [19] investigated whether men and women define leadership differently when working in interdisciplinary teams. Male students defined leadership more as directing teamwork, running meetings, and project oversight, while female students saw leadership as facilitating collaboration among team members, being responsible, and contributing to the team.

The participants of one study [30] were not only from engineering majors but from various STEM disciplines students taking a biology course, yet we use this study because the study had an interesting finding which is likely to be valid in the classes with only engineering students. Snyder et al. [30] used the Peer-Led Team Learning model to increase the success of underrepresented minority students. The PLTL model included small teams with six to eight students who were led by an undergraduate peer leader who had taken the course previously. These undergraduate leaders helped students were not experts or tutors but had been trained to help students in teams to learn concepts of course. This study found a significant improvement for students overall and especially for URM students. Only 10 percent of URM students failed or withdrawal in the course while this rate for students who did not enroll the PLTL model was about 40 percent. Another study [27] implemented the PLTL model in different majors including civil engineering. In this study, they selected peer leaders among minority students. They also find a positive effect for minority students using the PLTL model. Together, these studies suggest that we can increase the success of underrepresented students in teams using Peer-Led Team Learning.

### **Peer Evaluation**

One paper was about the difference in peer rating between female and male students, and minority and non-minority students [26]. Although this study was about peer rating, they considered the effect of gender and ethnicity as a part of the study. According to this study, there was no significant difference based on the gender of the rater or the person being rated. However, the difference between minority and non-minority students was significant; non-minority students gave higher ratings to other non-minority students compared to minority students. Minority students gave in one class more than six percent higher ratings generally compared to non-minority students.

### **Perception of professors and students**

Two papers were about the perception of professors about gender and race [22], [28]. Beddoes and Panther [22] interviewed 39 professors to understand what engineering professors thought about gender in teamwork. The authors reported the results for team formation, and team facilitation and student experience: For team formation, they found that professors give little attention to gender when they form teams, and often had no rationale behind the strategy they had for team formation. Some professors believed that they should not consider gender in forming teams because in the real world you cannot choose whom you want to work with. Some professors intentionally put more than one woman in each team. One professor put only one woman in each team to give a chance to female students to be the team leader because women tend to be the leader in teams (presumably an anecdotal impression, although the work of Rosch et al. mentioned earlier seems to support this).

Another professor was worried about considering any strategy for putting women in teams because he was concerned the university might fire him for treating women differently. Two other professors considered functional roles when forming teams; one said that all students should experience all roles in teams, while another set a rule that female students should not be note-takers in teams. Also, related to team facilitation and the students' experiences, some professors did not notice any gender bias in teams, some noticed but did not know how to intervene, and others noticed gender bias but viewed it as preparation for the workplace rather than as a problem.

In the second study, Mead et al. [28] used faculty interviews and student focus groups to find faculty and student expectations about teamwork training and group dynamics. The authors provided some results related to gender and race. According to this study, half of the faculty did not believe that gender and race had an influence on team performance. Other faculty had different opinions about gender. Some faculty preferred mixed-gender teams, and some believed that it is not a good decision to put one woman among men in the team. Some teams experienced conflict due to men ignoring women, which led the women to stop collaborating with others. A few faculties reported women as successful team leaders and some faculty reported that men are better leaders. Students also provided some opinions about gender and race. They expressed that women often are given less responsibility than men, especially in first-year and sophomore teams. They believed that women tend to get less attention and respect from their teammates. Students did not comment on race as much as gender. However, the authors reported that African-American students gave higher priority for having a social relationship with their teammates, and they preferred that team leader be selected by people outside the team.

### **Team effectiveness and outcome**

Five papers addressed team effectiveness and outcome [25], [16], [24], [13], [14]. McSpadden and Kelley [16] used diverse design teams to solve real-world problems. Students were given the task of the real-world problem that was culturally and socially relevant. This was intended to make the project attractive for female students because female students tend to prefer design-oriented activities that focus on social issues in addition to solving problems [31]. The authors argued that this kind of project provides an opportunity for both female and male students to learn how their strengths can be applied in the real-world problem through engineering. The authors combined the skills and interests of both female and male students to make cohesive teams, design, and projects.

Godwin et al. [25] studied students' attitudes about diversity after working on diverse teams and how their experience affected students' teamwork skills. The authors considered multiple facets of diversity including gender, race, and cultural difference. Some results of this related to gender and race: Students had a small, but significant, improvement in their attitude about diversity in a single semester. They became more willing to work in diverse teams and understand the importance of diverse teams. The students' focus on the race and gender differences decreased during the semester because they had a group discussion about the importance of diversity in teams. Working in diverse teams also increased the teamwork skills of students. However, there were some significant negative changes in the opinions of



students about including diversity in an engineering curriculum or teaching diversity by university professors. Also, students did not have the motivation to combat racial bias where it existed in teams.

Fila and Purzer [24] investigated whether gender diversity adds the number of creative solutions in design team projects. They found that gender-balanced teams did not have more creativity for developing design proposals comparing to all-male teams. But, gender-balanced teams that found more possible solutions could progress toward developing final design proposals with more creativity. Gender-balanced teams with high conflict among team members could not generate an idea and create innovative final projects. For having more innovative solutions in design projects, Fila and Purzer [24] suggested that instructors avoid forming teams only on the basis of gender and that they facilitate teams during teamwork.

Ertas et al. [14] tested the transdisciplinary (TD) pedagogy in undergraduate research teams. The authors investigated TD's impact on the learning outcomes of male Caucasian and male underrepresented minorities students. This approach increased the engagement of underrepresented students in teams. Due to the engagement, collaboration, and support that underrepresented students experienced in this pedagogy, their learning improved.

Chen et al. [13] studied the self-efficacy in different ethnic groups after working on collaborative project-based learning (CPBL). They conducted this study for undergraduate senior-level engineering students who worked on team projects in an urban environment. Whereas Hispanic students had lower domain-specific self-efficacy before the study, their self-efficacy developed more than other groups through CPBL. The authors explained that the most possible reason for this self-efficacy improvement is Hispanic students benefited from social characteristics of the learning environment. Peer discussion helped Hispanic students to evaluate the quality of their work.

### **Team Formation**

We covered some results about team formation in the perception of professors' section [22]. In addition to this study, another paper was about the effect of gender on team formation. Laeser et al. [15] formed four team types; all male, majority male, majority female, and mixed (half female and half male). They found no significant difference between male and female students in team functions. Teams with majority male students exhibited more clarifying function (interpreting ideas or suggestions, defining terms, clarifying issues, or clearing up confusion) than majority female student teams, and in majority male teams, males had more clarifying roles than females. On the contrary, in majority female teams, females exhibited more clarifying behaviors than males. Majority male teams displayed more encouraging function (being friendly, warm, or responsive, indicating acceptance of others' contributions) than majority female teams. In mixed teams, males had more standard setting function (expressing standards for the team to achieve or applying standards in evaluating the quality of team process) than females, but males and females had equal standard settings in majority male teams. In the first final report, mixed teams had the lowest performance. Majority male teams produced higher quality final reports in the first course's final report

than majority female teams, but female majority teams delivered higher quality report than majority male teams in the second course's final report.

## **Discussion**

By having results related to the race and gender, we discussed these results for each category separately:

### **Collaboration**

Although only three papers studied the collaboration, positive attitude of women about collaborating was obvious. Female students are more likely to prefer collaboration than male students. However, the mode of collaboration is very important. If female students have the same opportunity as male students to participate in teams and freely express their opinion, the collaboration would be effective and result in less conflict in teams. Instructors must be cautious about any decision that might result in a negative mode of collaboration. For instance, putting more male students in a team or assigning a leadership role to men could bring negative results for teams.

### **Communication**

Communication is very important in teamwork because if teams want to work for a long time together, any problem in communication could initiate a problem in teams. The paper related to the communication suggested that although there is no bias against the physical gender of the speaker while speaking in the teams, men in engineering enact and expect masculine interaction norms. Preferring male norms in communication by male engineering can have significant negative consequences because male students might think female students are bad team members just based on their communication patterns. If female student describes her work as not good enough just because she likes to deliver better work, male students might interpret that she is not competent. Even if this female student does better work than male students, this misinterpretation of female speech might have that result that male team members disregard her work. While the Wolfe and Powell' study [17] targeted only small-scale interaction in teams, the result is important because these small biases are similar to microaggressions that make bigger problems over time.

### **Leadership self-efficacy**

The first study in this section proved that female students have a higher motivation than male students to lead teams. They have a strong belief that they can play leadership roles. However, male students do not trust the leadership of females as much as females believe themselves. The result from [18] showed that even though males rated the females' leadership competency higher comparing to the females' ratings of males, male students still did not believe in the leadership ability of female students as much as females themselves believe.

Based on the Rowan-Kenyon et al. [19]'s study, if a female student could lead a team, it would be useful for teams because females tend to define leading as facilitating team and

having the responsibility toward teams. This may cause conflict with male notions of leadership, so some instruction may be necessary to legitimize alternative approaches to leadership. In addition, the last two studies in this section proved in teams that are led by students, underrepresented students showed better performance. These results highlight the importance of leadership roles for all engineering students including minority students. Leadership roles might be taught when teams will have a designated leader.

### **Peer Evaluation**

A study conducted for peer evaluation revealed that women and minority students are vulnerable to receiving the lower ratings from other students. If peer evaluation has a significant effect on the grade of the course, engineering instructor must be cautious about this effect. However, only one study covered this area [26]. Although this study sheds light on the important aspect of teamwork, for having a good discussion we should consider more recent and more detailed studies on the effect of peer evaluation on race and gender.

### **Perception of professors and students**

Although based on the Beddoes and Panther [22] students believe that gender is an important issue in teamwork, both studies revealed that professors give less attention to gender issues and varying opinions about it. Each professor interprets gender in teamwork differently and some choose to ignore this issue because this problem also exists in workplaces. However, the perception of professors is really important about teamwork because these insights shape any decision related to the forming teams or facilitating teams. We also found that professors ignore facilitating teams or are not able to facilitate. This cannot be good news for engineering because if students do not learn to solve problems related to gender or race in teamwork at universities, we cannot expect to solve these issues in the engineering workplace. If we assume that gender issue does not matter in engineering classes because there is the same problem in the engineering workplace, it means that we accepted this problem as a nature of engineering rather than finding solutions.

### **Team effectiveness and outcome**

Interpreting the result from Ertas et al. [14], we can say that minority and underrepresented students will have better team outcomes if instructors use effective pedagogy for teaming. Students will collaborate more with other students if they are engaged in teamwork. Also, considering the result of McSpadden and Kelley [16], one suggestion for engaging women is considering the social issues of engineering problems while students want to find a solution for an engineering problem. Women tend to be more willing to engage in teams if they feel that teams working on the project that will be useful for humanity. In addition to female, African-American students tend to want to have a social relationship with other team members. So, if teams integrate social and academic activities, African-American students could have more motivation for teamwork. As Chen et al. [13] reported, the self-efficacy of Hispanic students in urban areas improved significantly after collaborating with other students in projects because Hispanic students believed in their abilities after other students assessed the quality of the Hispanic students' work. All these findings of women and ethnic minorities prove the importance of suitable pedagogy for teaming.

In addition, training students about diversity is useful for engineering students before, during, and after working on teams. This training will have more effect on the opinion of engineering students about diversity if it continues during all semesters. In addition to training students, facilitating teams can make diverse teams more effective. Since diverse teams have good potential for diverse ideas, facilitating is necessary for helping these new ideas flourish.

### **Team Formation**

Because only one study on 2003 is analyzed in this paper [15], we discuss this section with caution. Although majority-male teams had better performance for two team functions, there was no significant difference between majority male and majority female students in the other eight functions. Also, overall, females and males had equal performance. As a result, according to this study, there was no serious negative effect on gender in the team formation. As we discussed earlier many factors could affect gender in teamwork such as mode of collaboration or attitude of engineering students. We also saw that each professor seeing the gender in team formation from a different viewpoint. Obviously, if team formation does not affect gender issues in teamwork directly, it could make worse other problems that are mentioned in this paper. However, this area must be studied more by engineering education researchers.

### **Limitation**

For this paper, we only searched four databases. There might be more articles about teamwork in other databases. Another limitation might be our research strings. We used the best possible strings we could identify, but some relevant papers might not have appeared using these strings. We also limited our results to only U.S. institutions and papers that collected the data in the U.S. universities. So, we excluded any paper that we were not sure had collected data in the U.S. universities. If we included universities from other countries, we would find more results. We also limited our results to undergraduate students while there were some papers for graduate students' teamwork. Finally, since we wanted to find the more focused result, we only targeted race and gender while there are other types of diversity that could be investigated.

### **Conclusion**

In this paper, we analyzed papers from four databases to find which factors related to the team experience of women and minorities has been investigated by engineering education researchers. Based on the findings, researcher investigated the experience of women and minorities in mode of collaboration, communication, leadership self-efficacy, peer evaluation, team formation, team's performances, and the perception of professors and students about race and gender. In a summary, women have positive attitude against collaboration, but prefer dialogic collaboration comparing to hierarchical modes. Women have higher motivation for leading teams. They prefer to solve real world-problem while working in teams. Men in engineering are harsh on the feminine speech styles and do not believe in the leadership ability of women as women believe themselves. Also, minority students will benefit if instructors use effective pedagogy for teaming and use peer-led teams.

Although forming teams based on gender do not affect the performance and innovation in teams, teaching diversity to students is necessary.

Based on the results, we suggest that engineering instructors should consider both gender and race in any decision about teams from the beginning until the end of the semester. Before forming teams, the perception of students about gender and race could affect teamwork, and after forming teams, mode of collaboration, quality of peer evaluation, the strategy of team formation, and communication among team members can raise issues related to the gender and race. These problems can be solved by educating students to deal with possible issues and understand the importance of diversity. Also, facilitating teams during the semester is essential for reducing any conflict related to gender or race. But, the most important one is the perception of professors because no problem can be solved if professors do not believe the importance of gender and race in teamwork

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